Discourse and Situated Learning in Math Teacher Twitter

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Abstract

Math Teacher Twitter is considered by some to provide an important example of contemporary professional development that can take place within a virtual participatory media platform. This study investigated the phenomenon of Math Teacher Twitter by analyzing a dataset of 9881 tweets associated with 3133 profiles obtained by querying the Twitter API using a set of four key Math Education Twitter Hashtags (METHs), `#mtbos`, `#iteachmath`, `#mathchat`, and `#math`. Investigating the discourse features *hashtags used*, *tweet content*, *discursive style*, *values expressed*, *profile content*, and *engagement*, allowed a description of the Twitter discourse associated with Math Teacher Twitter to be developed. Particular patterns of hashtag use, discursive style and value expression were associated with a difference in engagement, topical relevance, and profile descriptions. The elements of this Twitter discourse were further analyzed from the perspectives of two models of situated learning: the *affinity spaces* and *communities of practice*. This analysis suggested that while the affinity space model provides helpful descriptions of particular features of Math Teacher Twitter, the critical perspective provided by the communities of practice model remains helpful in understanding the underlying dynamics of this phenomenon. The methodological and theoretical implications of these findings for researchers who wish to observe and understand Math Teacher Twitter are discussed, along with some practical implications for its participants.

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Chapter 1

Introduction

The phenomenon of *Math Teacher Twitter*, the sharing of content produced by or for mathematics educators on Twitter, has found its way into many discussions about the current state of the professional development of mathematics teachers and its future. Slama et al. (2021, October 13) refer to the online "teacher-led math community" on Twitter as an innovative "point of light" that stands out against a background of "steady state" traditional professional development options of questionable effectiveness (p. 17) while in a blog post, Orlin (2021) advises that "Twitter is arguably the cheapest and most powerful form of ongoing professional development for math teachers." These positive appraisals are not uncommon. More generally, the professional use of participatory media by teachers is seen by some to be a required supplement to traditional professional development practices (Adjapong et al., 2018), or even a potential replacement for them (Forte et al., 2012). The consensus view is that Twitter has emerged as a platform of choice for teacher professional development using participatory media (Carpenter & Krutka, 2014). Researchers have also argued that Twitter can act as a *foundational technology* for educational professionals in how it can be adapted to serve multiple purposes across a wide spectrum of professional development contexts (Greenhalgh et al., 2016). The interest in teachers' professional use of Twitter and the professional development opportunities that it may facilitate make Math Teacher Twitter a phenomenon that warrants investigation and critical attention.

Research Questions

Unofficial, unplanned, and not associated with any particular curricular or regional initiative, how can activity on Twitter be considered professional development? The Organization for Economic Cooperation and Development (OECD, 2009) takes a broad approach to defining teacher professional development, stating that "professional development is defined as activities that develop an individual's skills, knowledge, expertise and other characteristics as a teacher"

(p. 49). Noting that professional development encompasses a wide range of structured and unstructured activities, OECD (2009) found that the most prevalent form of teacher professional development under this general definition was unstructured and best described as "informal dialogue to improve teaching" (OECD, 2009, p. 57). This unstructured and dialogue-based form of professional development seems to offer a possible way to understand Math Teacher Twitter as professional development. However, a more detailed understanding of what "informal dialogue to improve teaching" might look like within the Twitter environment is essential to deciding whether this description is appropriate. A first step in comparing teacher activity on Twitter with more recognizable forms of dialogue that are associated with professional development is to note that the *text* based interaction of online platforms can be much closer to *talk* based dialogue than more traditional forms of textual expression and that platforms such as Twitter provide particular affordances that allow *metameaning* to be expressed in new ways (Tannen, 2013). To capture the complexity and potential expressiveness of the interactions on these platforms, the more general term *discourse* is used to avoid a false distinction between text and talk and to highlight the presence of non-textual signals of metameaning provided through platform affordances. These considerations lead to the first research question:

> *RQ 1: What are some of the important characteristics of the discourse associated with mathematics educators' informal professional development on Twitter?*

Beyond describing the characteristics of the discourse that makes up Math Teacher Twitter, it is important to be able to link these characteristics to ways of understanding professional development. *Situated learning*, which describes learning as "supported in part through social interaction and the circulation of narrative" (Brown et al., 1989, p. 40), provides a possible means by which we can interpret the unique social discourse of the Twitter platform as part of educators' professional development. As theories of situated learning have developed, different models of situated learning have emerged, including the *legitimate peripheral participation* or *community of practice* model (Lave & Wenger, 1991) and the *affinity space* model (Gee, 2004).

The *community of practice* model (Lave & Wenger, 1991) of situated learning describes learning as a process of identity formation by which newcomers are gradually recognized as practitioners through participation within a community of practice; learning is a means of community reproduction and renewal which to the learner represents a passage from the periphery into being a full member of the community. While the community of practice model has been transformational in understanding professional learning and in defining what effective professional development can look like, this model has been contested by other ways of thinking about situated learning that play down the importance of community, membership, and identity. Primary among these other understandings of situated learning, the *affinity space* model (Gee, 2004)

describes learning as a process that occurs in spaces that facilitate interactions among individuals who come together to solve problems of mutual interest. By providing language that helps describe real and virtual learning spaces, affinity spaces have become a prominent way of describing teacher professional development activities on Twitter (see, for example, Carpenter and Krutka, 2014, Rosenberg et al., 2016, and Greenhalgh and Koehler, 2017). Considering how to interpret the characteristics of Math Teacher Twitter discourse in terms of potentially competing models of professional development leads to the second research question:

> *RQ 2: How do theories of situated learning, such as the community of practice and affinity space models, help us understand the informal professional development practices of mathematics teachers on Twitter?*

Researchers have identified *hashtags* as an affordance that allows researchers to investigate communication on Twitter related to teacher professional development (for example: Greenhalgh et al., 2016; Rosenberg et al., 2016; Staudt Willet, 2019). While many studies that broadly investigate teacher professional development on Twitter have made use of well-known hashtags such as `#edchat`, knowing which hashtags may be used to investigate the more narrowly defined phenomenon of Math Teacher Twitter presents a problem. The current study first addresses this preliminary question: "what key hashtags are used in Math Teacher Twitter?" After identifying these hashtags, the research questions are addressed by analyzing a corpus of tweet data obtained through hashtag-based queries using the Twitter API (Twitter Inc., 2019).

Structure of the Thesis

Chapter 2 provides a literature review that describes some of the key contributions that have been made to the study of how teachers use Twitter for professional development and situates this phenomenon within the broader context of changing understandings of professional development and the emerging study of online behaviour. The relevant literature stretches back to surprisingly early contributions to our understandings of professional development, communications, and social learning, and also extends broadly into various fields that illustrate the multidisciplinary concerns that this topic touches on. The literature described in this section provides examples of the multiple methods of inquiry that are used in studies related to the research questions, and in particular how researchers have used Twitter data obtained through hashtag-based queries in studies of teacher professional development on Twitter.

Chapter 3 outlines the conceptual frameworks used in this study. This chapter first describes the models of situated learning that will be used to interpret Math Teacher Twitter as professional development and second provides an overview of Twitter discourse as is presented to both participants and researchers. The features of Twitter discourse identified in this chapter will

be used later to answer RQ1, while the conceptual components of situated learning outlined here will provide the means to develop an answer to RQ2.

Chapter 4 describes the methods used in the two-phase process of first identifying key hashtags used in Math Teacher Twitter and then using these hashtags to build a corpus of tweet data to answer the research questions. These methods include techniques of data acquisition and data analysis particular to Twitter API data. In phase one, an initial set of profiles was identified and used to create the *phase-one dataset* (MacKinnon, 2020a). Chapter 4 describes how this data was acquired and analyzed to identify key hashtags used in Math Teacher Twitter. The chapter then goes on to describe methods used to acquire and analyze the *phase-two dataset* (MacKinnon, 2020b). The phase-two dataset provides the corpus of tweets analyzed to answer the research questions identified by this study.

Chapter 5, analyzes the corpus of tweet data furnished by the phase-two dataset to respond to the first research question. A description of the Twitter discourse of Math Teacher Twitter is developed by analyzing the phase-two dataset in terms of identified features of Twitter discourse (described in Chapters 3). The description that emerges reveals high-level patterns that connect multiple discourse features, for example showing connections between hashtags used, discursive styles, and profile content.

In Chapter 6, the important discourse characteristics of Math Teacher Twitter are viewed through the lenses of the selected models of situated learning. The interpretations furnished by these models of situated learning are used to provide an answer to this study's second research question. The final chapter, Chapter 7 reflects on how these descriptions and interpretations (along with the methods used to obtain them) allow the emerging phenomenon of Math Teacher Twitter to be understood as professional development and considers the implications of these understandings for practitioners and researchers.

Ethics and Positionality

This research relies on data obtained using the Twitter API and can be considered as an *unobtrusive observational study* (Hewson, 2017) of mathematics educators' use of Twitter as a means of informal professional development. Although this study has used publicly available data, the data acquisition process has not required direct interaction with subjects, nor has the data analysis required the reporting of personally identifiable information.

Researchers who make use of public Twitter data, as this study does, have asserted that "data from social media, particularly Twitter, qualifies as an exemption from strict ethical guidelines and considerations" (Rehm & Notten, 2016, p. 218). While it is assumed that publicly available Twitter data do not pose any overt ethical concern or risk to privacy, caution should

be exercised when presenting such data outside its original context. With this caution in mind, no personally identifiable information has been included in the data presented.

My own experience as a mathematics educator and participant/observer in Math Teacher Twitter helps inform my awareness of the practices and language of this particular group of educators. While the technology-mediated methods have not required direct interaction with the subjects of this study, my personal experience as a mathematics educator has informed my efforts to be reflexive, transparent, and sincere in observing and describing these subjects and how they are represented on Twitter.

Chapter 2

Literature Review

In this chapter, I will review the literature concerning informal teacher professional development activities on Twitter, paying particular attention to the shifting theoretical landscape and evolving methodological approaches associated with this topic. First, I will note how the perspective of situated learning has provided a foundation for describing effective professional development within the context of informal communities. Second, I will identify how these foundational ideas have been challenged when used to describe professional development in online settings, where difficulty in describing interactions in terms of enduring social bonds has led to a shift in theoretical perspectives towards models of situated learning that downplay the importance of community. In particular, I will outline a shift from the *community of practice* perspective toward the *affinity space* model of situated learning. A third focus of the literature examined in this chapter concerns the methods used by researchers in examining Twitter discourse. To better understand social interaction on Twitter, a key element across all models of situated learning, researchers have identified the *hashtag* as essential metadata that highlights both individual intention and social convention on the platform. Turning to the literature on this key affordance, I will note how hashtag use represents a wide and interdisciplinary area of interest, spanning the social sciences, linguistics, and computer science, and how hashtag use (along with other discourse features) has been linked to social behaviours that are of key concern within models of situated learning. Focusing on literature that looks more directly at topics related to this study's research questions, I will describe some recent studies of teacher professional development using Twitter that highlight the methodologies and understandings that have emerged in this area. Finally, I will note some critical perspectives on Twitter and participatory media that are relevant to its professional use by mathematics educators.

The Promise of Informal Professional Development using Twitter

Studies that have specifically looked at educator use of Twitter have found that K–12 teachers began turning to Twitter for professional development soon after its initial appearance as a microblogging platform (Carpenter & Krutka, 2014). This use is generally reported as enthusiastic, with some claiming it to be the "cornerstone of their professional learning" (Ferriter & Provenzano, 2013, p. 19), and the "best professional learning" they had experienced (Tour, 2017b, p. 183). It has been suggested that educators' professional use of Twitter has *redefined* what good professional development looks like (Britt & Paulus, 2016). Understanding the phenomena of teacher professional use of Twitter and how it has been interpreted requires us to situate our thinking about this practice within the context of an ongoing and evolving critique of traditional teacher professional development. Part of understanding this context requires recalling that traditional teacher professional development is conventionally understood as in-service staff development efforts initiated by schools, school boards, and education ministries engaged in school improvement or curriculum change. Professional development in this traditional form has been judged as out of touch with contemporary understandings of cognition and learning (Borko, 2004). As noted by Brooks and Gibson (2012):

> Traditional professional development models that reinforce an externally designed, stand and deliver, nonparticipatory type of learning environment do little to assist teachers in enacting constructivist, inquiry-based learning practices, commiserate with 21st Century learning, in their classrooms. (p. 11)

In contrast to the traditional model, contemporary understandings of teacher professional development suggest that it should recognize the situated, social, and distributed nature of cognition and learning (Putnam & Borko, 2000). As Borko et al. (2010) notes:

> Most experts in the field advocate moving away from an in-service training model, where teachers are expected to learn a clearly defined body of skills through a well-specified process, often delivered in one-shot workshops or courses taught away from the school premises. These traditional approaches are generally viewed as overly fragmented, not connected closely enough to classroom practice, and out of alignment with current theories of learning and school reform. They are being replaced by approaches that are more closely aligned with constructivist and situative theories and reform efforts; specifically they are grounded in classroom practice and involve the formation of professional learning communities. (p. 548)

Participatory media, such as Twitter, seems in some respects well-suited to support this contemporary understanding of what effective professional development should look like (Car-

penter & Krutka, 2015). Rather than being externally designed, teacher professional development on Twitter is grassroots (Forte et al., 2012) and self-generating (Prestridge, 2019). As a social-networking site, Twitter supports discussion around topics that reflect individual teachers' questions and inquiries. Always available, unlike occasional disjointed PD sessions, Twitter seems accessible, and its use can be less removed from teachers' daily life and professional practice. As Carpenter and Krutka (2015) conclude, "for teachers unsatisfied with the PD available to them through their school, district or other conventional avenues, Twitter may offer an efficient and personalized alternative means of professional learning" (p. 722). Not merely an alternative to traditional professional development, teacher use of Twitter is seen by Forte et al. (2012) as "a foundation for education reform" (p. 112). When considering the broader context of how new forms of professional development are being understood, it is important to also appreciate that communication technology's potential for disrupting and redefining professional learning has been long anticipated. While the particular platform may be relatively new, the potential for peer matching through computer-based "learning webs" within a "global village" has been championed as a convivial successor of traditional modes of schooling and certification since the late 1960s and early 1970s (Fiore & McLuhan, 1967; Illich, 1971).

Professional Development and Models of Situated Learning

As described by Lave and Wenger (1991), the analysis of learning as *legitimate peripheral participation* within a *community of practice*, has strongly influenced contemporary understandings of effective professional development (Borko et al., 2010; Goos, 2014). In particular, the community of practice paradigm responds to the critique of top-down teacher professional development in its valuing of self-directed, informal, and teacher-led professional learning, as noted by (Wenger, 2011):

> . . . it allows us to see past more obvious formal structures such as organizations, classrooms, or nations, and perceive the structures defined by engagement in practice and the informal learning that comes with it. (p. 3)

Part of the appeal of the community of practice model is in how it allows room for teachers to reconceptualise "colleagues" in a wider sense as fellow practitioners, rather than exclusively understanding them as other teachers from the same school, district, or region: the community of teachers may not be co-located, but meets (in the widest sense) in some way around a shared practice. It is not surprising that the informal and boundary-crossing community of practice model has been applied to online interactions, where it has been translated into a constellation of models of virtual communities (Dubé et al., 2006; Henri & Pudelko, 2003). These extensions

of the community of practice model have been applied to online learning generally (see the surveys in Lantz-Andersson et al., 2018; Macià and García, 2016), and to teachers' professional development on Twitter specifically (Britt & Paulus, 2016; Gao & Li, 2017).

It has also been noted, however, that in terms of relationship building, increasing participation, and identifying the actual underlying practice, what can be observed in online professional development situations often falls short of meaningful definitions of "community of practice" (Trust, 2015). A discomfort in applying the concept of community of practice (or even the term *community*) to online activity has led some commentators and researchers to describe relationships formed online in terms of *networks* and, in particular, *personal learning networks* (Davis, 2015; Tour, 2017a, 2017b). The concept of a network deemphasizes an ambient culture or shared understandings; instead, connections are made between individuals based on personal interest rather than community identification. Looking at connections in this way raises the question of network formation: how do participants gather around a topic of mutual interest? The concept of *affinity spaces* (Gee, 2004, 2017) provides a topic-focused model for social interaction and learning that the question of online network formation demands, and goes further in diminishing the importance of even weak connections between participants. Instead of considering a community, group, or even relationships between individuals, this perspective looks at the (symbolic) space and the interactions that occur in this space, as (Gee, 2004) notes: "what people have an affinity with (or for) in an affinity space is not first and foremost the other people using the space, but the endeavour or interest around which the space is organized" (p. 84). In these contexts, Gee (2004) suggests that "it is not clear that membership is a truly helpful notion" (p. 77). Rather than being identified by membership, "affinity spaces are primarily defined by an affinity for solving certain sorts of problems" (Gee, 2017, p. 28): people are attracted to spaces due to an *affinity* for a topic or problem, rather than being associated with it due to a community *affiliation*.

Twitter Discourse and the Role of Hashtags

While Twitter does not provide an explicit mechanism for topical forums such as those that provide the canonical example for affinity spaces (Gee, 2004), the *hashtag* has been identified as the affordance that Twitter provides for participating in topical conversations – an essential feature of learning across situated learning models. Several studies have looked at the use of particular education-focused hashtags, such as `#edchat`[1] (Britt & Paulus, 2016; Gao & Li, 2017; Staudt Willet, 2019), regional education hashtags (Greenhalgh et al., 2018; Rosenberg et al., 2016), or other course-specific hashtags (Greenhalgh et al., 2016). Within these studies, hash-

[1]Here, all hashtags will be written in lowercase. Search based on Twitter hashtags is case-insensitive, but users may include capitalization, such as `#EdChat` or `#edChat` that distinguish combined terms or keywords within an acronym or concatenation of words.

tags, used to facilitate interactions that extend beyond particular follower networks, have been identified as a mechanism for enabling professional development activities on Twitter (Carpenter et al., 2019):

> Hashtags appear to play an important role in educators' Twitter use by facilitating initial connections and ongoing conversations between geographically dispersed educators who share common interests and/or goals. (p. 2)

Studies of the use of hashtags drawn from a variety of research perspectives have indicated that, in addition to providing access to topical conversations, they can perform other important social functions. In particular, studies of social tagging systems such as Twitter have noted that hashtags do not provide a strict taxonomy and ordering of content, but rather allow for a *folksonomy* (Vander Wal, 2007; Zappavigna, 2015) of constantly evolving and negotiated classifications and conventions. Presenting both choice and adherence to convention, the use of hashtags becomes an occasion for distinction and imitation, leading to a wide variety of social uses. Hashtags, may be idiosyncratic and meme-like (Bruns et al., 2016; Page, 2012), or be employed to signal opinion or emotion (Zappavigna & Martin, 2018). A powerful and flexible metalinguistic feature, hashtags both define an "imagined audience" (Zappavigna, 2015, p. 275) and a means of expressing identity and membership (Page, 2012; Smith & Smith, 2012). These studies, which have made use of a variety of software methods and tools to analyze large sets of public Twitter data, suggest that hashtags can play a key role in understanding social interaction on Twitter, and consequently in understanding any situated learning that may be occurring there.

Studies of Teacher Professional Development on Twitter

In this section, I will review specific studies that have looked closely at various aspects of online teacher professional development using Twitter. The particular studies highlighted here have contributed to the development of research methods and perspectives, particularly when investigating hashtag-mediated use of Twitter viewed through the lens of situated learning.

Forte et al. (2012) took a mixed methods approach (survey, interviews, and analysis of Twitter data) to understand how teachers make use of Twitter and other social media in their professional lives. The analysis of Twitter data consisted of coding the content of tweets that used the `#edchat` hashtag according to a grounded theory approach, where the codebook was developed through analysis of tweet content as well as interview and survey results. Forte et al. (2012) found that the most commonly reported and observed use of Twitter by teachers was to connect with other educators outside their immediate local school area, primarily for resource sharing. Twitter use in this study is seen as a teacher-driven "bridging" activity that is useful for

the import of progressive and innovative ideas from more distant teaching colleagues into "local communities" (p. 106).

Carpenter and Krutka (2014) used a survey-based approach to answer the questions "how and why do educators use Twitter?" and found that professional development (characterized as resource sharing and connecting with "digital" colleagues) was the most frequent use, over its direct use in educational activities and as a means of communicating with students and parents. Hashtags, predominantly the `#edchat` hashtag, were identified as a key way that educators went about "connecting with colleagues around topics of interest" (p. 422). Educators reported that the professional development that Twitter afforded was efficient, accessible, and personalized, and that the interaction on the platform helped to combat feelings of isolation while promoting a sense of community (p. 426). Carpenter and Krutka (2015) took a closer look at the respondents to their original study (Carpenter & Krutka, 2014) that identified professional development as their primary reason for using Twitter. Invoking the idea of *affinity spaces* (Gee, 2004), Carpenter and Krutka (2015) noted that "respondents often described Twitter as a space of enthusiasm, invigoration, empowerment and connection" that allowed them the autonomy to self-direct their own professional development (p. 722).

Rehm and Notten (2016) reviewed of the various ways online teacher professional development has been described and settle on *social capital* accumulation as a useful concept for describing the benefits and dynamics of teacher professional development activities on Twitter. The concept of social capital expresses the idea of relational resources that can be transformed into other forms of capital or act as multipliers of effectiveness in social exchanges. A distinguishing feature of this study is that while investigating activity related to a hashtag (in this case `#edchatde`), it examined metadata rather than tweet content. The perspective taken here is that addressing and being addressed by other users in Twitter exchanges provides a structural expression of social capital. Tweet metadata, such as *mentions* and *replies-to* were used by Rehm and Notten (2016) to trace social networks, to which measures of centrality were applied in order to assess expressions of social capital. It was observed that over time, "participating in a hashtag conversation on Twitter does indeed contribute to individual teachers' formation of structural social capital" (Rehm & Notten, 2016, p. 220).

Rosenberg et al. (2016) explicitly associated hashtags with affinity spaces in an investigation of "State Educational Twitter Hashtags" (SETHs). SETHs, of which 47 were identified in the study, are hashtags that generally use standard Twitter conventions to indicate that they are concerned with educational topics specific to a certain region, such as `#nyedchat`[2]. This study used data from the Twitter API, collecting large numbers of tweets over an extended period.

[2]Similarly, in the Canadian context there are *provincial* education Twitter hashtags, such as `#oned` and `#onted` for "Ontario education."

Commenting on the use of these SETHs, Rosenberg et al. (2016) notes:

> These hashtag-based spaces seem to be teacher-driven, public, largely unmoderated and thriving. The apparent qualities of these informal, Twitter-based interactions among teachers could change the way that we conceive of teachers' continuing professional development. (p. 25)

Rosenberg et al. (2016) noted that the interaction (volume and engagement metrics), apparently voluntary nature (activity outside of school hours), and teacher-driven nature (based on profile assessments) of the activity within SETHs provided indications that they could be legitimately and constructively described as affinity spaces.

Greenhalgh et al. (2016) noted that "Twitter is becoming increasingly accepted as a powerful technology for educational professionals," but assert that rather than being a tool with a specific well-defined purpose, it may be considered as a foundational technology that can be adapted for use under multiple circumstances (p. 82). To investigate this idea, Greenhalgh et al. (2016) looked at the Twitter use of students enrolled in an educational technology graduate program, querying for tweets using 12 known hashtags associated with courses in the program. In this study, tweet content was analyzed using a grounded theory approach which identified a set of themes by which the tweets were classified. Greenhalgh et al. (2016) argued that the different themes that emerged from looking at tweet content "represent different purposes that Twitter serves in this community" (p. 94).

Gao and Li (2017) investigated a one-hour synchronous session of `#edchat`[3], looking at tweet content along with *mentions* and *replies* which allowed the construction of an "interaction network." It was observed that most activity and content was provided by a small group within the set of participants, reflecting the power law, or one-percent rule, that has been frequently observed to describe participation in online groups (Carron-Arthur et al., 2014; Van Mierlo, 2014). The one-percent rule provides a heuristic that reminds us that many who participate in online group interactions are passive observers, or perhaps interact in ways that are not obviously reflected across all measures of activity (these participants may follow links, press the like button, or add the profile from the tweet to their friend list). It was also observed for this instance of the synchronous chat that the discussion touched on several issues relating to the chosen topic, suggesting to the researchers that "such online chat could be a potentially useful activity to help participants gain multiple perspectives on the topic discussed"(Gao & Li, 2017, p. 342).

Greenhalgh and Koehler (2017) investigated the use of Twitter by educators to gain access to "just-in-time" professional development (a concept defined in Plair, 2008) in response to a

[3]Volunteer moderators host a daily synchronous discussion using the `#edchat` daily at 7 p.m. Eastern time, while asynchronous use of the hashtag can occur at any time (Edchat wiki contributors, 2021).

challenging and tragic event (in this case, the terrorist attacks that occurred in Paris on November 23, 2015[4]). In the days following this event, a hashtag, `#educattentats` was used by several educators to share ideas and resources to discuss attacks with their students, which Greenhalgh and Koehler (2017) identified as an example of an affinity space. The perspective taken by Greenhalgh and Koehler (2017) was that Twitter provides a forum for "a kind of social learning that happens through affinity spaces" that are defined through hashtags (p. 273), and argue that the characteristics of the interactions observed indicate that the content and metadata characteristics of the tweets using the `#educattentats` hashtag showed evidence of just-in-time professional development.

Adjapong et al. (2018) employed a questionnaire distributed to educators using the `#hiphoped` hashtag to explore how participating in the Twitter chat organized around that hashtag functioned as professional development for teachers integrating Hip-Hop culture into their teaching practice. A key finding of Adjapong et al. (2018) was that the chat organized around `#hiphoped` was a situation where "outsiders of Hip-Hop culture are provided opportunities to begin to develop their cultural competence" (p. 34).

Carpenter et al. (2019) employed a very large dataset of teacher Twitter profiles (33,184 profiles) and tweets (15.9 million tweets) to investigate how the profiles reflected "non-professional identification," and which hashtags were used in tweets by teachers. From the Twitter profile data, text-mining techniques were applied to profiles to extract terms that users employed in self-description and identification. Self-identification included terms that pertained to family status, religious beliefs, and political orientation. To these categories, the school associated with each teacher allowed teachers to be identified as working in a private or public school, elementary or secondary, rural or urban, along with economic indicators (schools that provide subsidized lunch programs, and those identified through the US Every Student Succeeds Act). Carpenter et al. (2019) found that "teachers more commonly shared their familial roles than their political or religious leanings" (p. 8). The relatively low frequency of political and religious identification was interpreted to represent an attempt by teachers to present themselves as professionals (Carpenter et al., 2019, p. 6), and teachers serving less prosperous school populations were less likely to disclose familial roles or status information.

Staudt Willet (2019) revisited the survey findings of Carpenter and Krutka (2014) through an *inductive exploration* of Twitter API data obtained through queries of the `#edchat` hashtag. Staudt Willet (2019) asserts that on Twitter "affinity spaces rely upon hashtags as the primary organizing feature" (Staudt Willet, 2019, p. 274), and that `#edchat` was selected due to its longevity and popularity. Identifying tweet purposes as being related to *self*, *others*, *mutual*, and *miscellaneous* and differentiated between tweet types such as original posts and retweets (of vari-

[4]For context, see for example Schofield (2021).

ous forms). Staudt Willet (2019) found that the majority of tweets in the #edchat corpus of the study was *peer-retweets* (distinguished from self-retweets) making up 57% of tweets, and 64.66% of tweets had purposes related to the *others* category (reaching out to others, acknowledging others, etc.). In this study, Staudt Willet (2019) provides a useful overview of the purposes and types of tweets associated with #edchat, and arrives at suggestions on how to situate data-driven explorations of Twitter API data in relation to studies that are based on surveys, interviews, and other computational methods.

Carpenter et al. (2020) stated that while hashtags can be used to facilitate teacher's professional learning, popular hashtags "can prove an enticing target for spammers who attempt to redirect users' attention" (p. 461). Spam presents a problem for social media participants and researchers as well: it is tempting for researchers to filter out spam when analyzing communication on a platform such as Twitter, but in doing so they may be neglecting an important aspect of participants' experiences. Carpenter et al. (2020) surveys a number of metrics for spam detection, including both profile and tweet features such as tweet volume, level of interaction, following/follower ratios, level of hashtagging, and levels of hyperlinking. Asserting that not all spam is unwelcome to all participants, Carpenter et al. (2020) noted that some announcements and even advertisements may come from reputable sources or from teachers themselves, and some of this content may be considered welcome and topical. Ultimately, Carpenter et al. (2020) recommend that researchers consider a holistic mixed methods approach to identifying spam in their Twitter data, to consider spam as a phenomenon rather than something that must be eliminated, and that teachers using Twitter for professional development become aware of the "many flavours" of spam (p. 468).

Greenhalgh et al. (2020) identified a range of different behaviour within a single hashtag-defined space, and suggested that multiple affinity spaces may be thought of as operating within the context of a single state education Twitter hashtag, #miched. Making an important conceptual statement Greenhalgh et al. (2020) suggested that, in general, affinity spaces provide a more useful framework than communities of practice when investigating hashtag-based interactions, because of the diversity of participants in these spaces, and the "low barrier for entry" that they provide (Greenhalgh et al., 2020, p. 3). This study found that within uses of #miched there are distinctions that can be made between those participating in synchronous chats and non-synchronous tweeting activity. The majority of tweets in the #miched corpus investigated were found to be non-synchronous, and these non-synchronous tweets were found to include more hashtags and involve more retweeting and resource sharing than the synchronous tweets, which were marked by more addressivity and engagement. Greenhalgh et al. (2020) argue that these distinctions should be interpreted as different *literary practices* marking distinct affinity spaces within the larger symbolic space defined by the #miched hashtag.

Larsen and Parrish (2019) looked specifically at mathematics educators' use of Twitter, focusing on the "MTBoS community." In this study, the MTBoS community is not strictly defined as those who use the `#mtbos` hashtag but primarily as individuals who have added themselves to the *MTBoS Directory* ("MTBoS Directory", n.d.); however, the "level of community participation" assigned to participants in this interview-based study (of five interviewees) was based on the number of followers of the participant's Twitter profile (Larsen & Parrish, 2019, p. 6). By investigating the characteristics of community building described in the interviews, Larsen and Parrish (2019) identified "a prominence of treating it as a place for resource exchange, and, to a large extent, resource consumption" (p. 12), in agreement with other studies that identified resource sharing as a primary component of online teacher professional development activity.

Relevant Critical Perspectives on Participatory Media

Understanding Twitter exclusively or primarily as a context for professional learning would require ignoring a significant dimension of how the platform is used and understood. While the already cited literature speaks to the role that Twitter can play in professional development, the platform is a general one that facilitates many overlapping forms of communication. In broader public conversations and in the wider research literature that is concerned with participatory media, Twitter and other participatory media platforms are frequently evaluated from standpoints that have little to do with their potential use in professional learning. Even when concerned with its potential use in teacher professional development, the diversity of uses of Twitter and the diverse ways of framing these uses should be acknowledged and examined.

Twitter has been examined in terms of its sociopolitical uses as a tool for protesters in organizing online campaigns or as a communications tool in situations of direct political action, and as a means by which those who hold political power can surveil such protests and movements (Tufekci, 2017). When considered in contexts that are less overtly political, as an information source Twitter has been criticized as creating "filter bubbles" that promote polarization (Pariser, 2011), facilitating the circulation of misinformation and propaganda. In contrast to perspectives that see Twitter as overtly political or polarizing, it has also been identified as a medium that is approached by its users with "cognitive laziness" (Pennycook & Rand, 2019), valued more for entertainment than information. Recognizing Twitter as a medium that can quickly transform perceived intimacy into public shaming and shared outrage provides yet another perspective that critiques both the personal and political aspects of Twitter (Nguyen, 2021b). While cited for its openness and potential for grassroots initiatives by many researchers who look at its use in professional development (Forte et al., 2012; Greenhalgh & Koehler, 2017; Greenhalgh et al., 2016, for example), more general perspectives describe it as a *symbolic marketplace* where ordinary users

compete with corporations and celebrities in an *attention economy* (Page, 2012). In evaluating how models of situated learning help us understand the professional development of mathematics educators on Twitter, consideration should be paid to how effectively those models address the multiple uses of Twitter, and how these models connect to more general understandings of participatory media.

Limitations of Existing Research

The research literature that has investigated educators' use of Twitter for professional development purposes has asked and answered many interesting and essential questions. Two areas that deserve additional attention include how interactions on Twitter are revealed and shaped by Twitter discourse features, and how adopting perspectives offered by particular models of professional development and learning determines the way those interactions are interpreted.

While many of the studies surveyed here have looked at Twitter hashtags as a key affordance in facilitating professional development on Twitter, hashtags have been primarily interpreted as topic markers, neglecting other uses of hashtags that the literature on social tagging outside the educational sphere has identified. Research that has focused on how professional development on Twitter coalesces around hashtags generally does not acknowledge the complex linguistic and performative roles these hashtags can play. In approaching the research questions about Math Teacher Twitter, the complexity of different hashtag uses should be considered. Among the simplifications that can occur, the decision of what hashtag, or set of hashtags, to study is sometimes presented as unproblematic. When a particular hashtag or set of hashtags is identified *a priori*, the data obtained through hashtag-specific queries are encircled by a firm perimeter that is artificial and does not reflect the experience of the participants. When data is obtained through hashtag-based queries, choosing which hashtags to examine is itself a problem that requires investigation, and any selection of hashtags to look at must be understood as imposing a limitation on what can be observed.

While researchers have noted the usefulness of particular framings of situated learning when investigating the professional development of teachers on Twitter, the implications of adopting particular perspectives on situated learning have not been fully elaborated. Identifying how the perspectives of communities of practice and affinity spaces, for example, pay attention to different aspects of situated learning should help make explicit what each model can contribute to our understanding of Math teacher professional development on Twitter. Contrasting the perspectives offered by different models of situated learning may also help to identify previously neglected aspects of informal online professional development using Twitter.

Chapter 3

Conceptual Frameworks:

Situated Learning and Twitter Discourse

This chapter will provide an outline of the *community of practice* (Lave & Wenger, 1991) and *affinity space* (Gee, 2004) models of situated learning, which the literature review of Chapter 2 has indicated may potentially describe phenomena such as Math Teacher Twitter. Several important components will be identified in describing each model. Along with these models, a conceptual framework for investigating Twitter discourse will also be described. Aspects of Twitter discourse that are of particular concern for situated learning will be identified and, for reasons described in this chapter, these discourse features will act as indicators of *topicality* and of *identity*.

Situated Learning

Traditionally, learning has been understood as a process of knowledge or behaviour acquisition by an individual and learned concepts have been seen as abstractions that can exist apart from particular situations. This traditional model has been critiqued as imposing an artificial distinction between *knowing* and *doing* (Brown et al., 1989). Models of situated learning distinguish themselves from this traditional view by focusing on aspects of learning which do not strictly pertain to individual learners, but rather are connected to situational context, practice, social interaction, and culture. Against approaches that see curriculum in terms of breaking down a subject into distinct units of knowledge that can be transferred and assimilated, situated learning asserts that what is learned cannot be separated from how it is learned and that knowledge is *co-produced* from situations and action (Brown et al., 1989).

Using situated learning as a way of understanding learning in online contexts may seem counterintuitive – online contexts may seem necessarily disembodied and distanced from actual

practice. To appreciate how situated learning can be meaningfully considered in technology-mediated contexts, it is helpful to keep in mind that situated learning views learning as a process of constructing concepts in the context of authentic activity in which narrative, social interaction, and "cognitive apprenticeship" play central roles (Brown et al., 1989). Informal online professional development, where peers exchange ideas and problems arising from their work, and where stories help establish a culture that recognizes shared struggles and values, can potentially provide the shared social context that situated learning theory asserts is essential to the learning process. The context of learning may be an actual real-world situation, but could also be a virtual one that provides an "anchoring" context (McLellan, 1994).

Communities of Practice

Lave and Wenger (1991) note that traditional theories of learning, and even many social learning theories, focus on a process of *internalization*, through which a learner appropriates cultural practices from external sources of knowledge. The *communities of practice* model promotes a more radical perspective on learning that attempts to avoid the dichotomy of interior and exterior, and instead presents learning as a sometimes conflictual sociocultural process of community renewal. Learning, in this view, is a process of *increasing peripheral participation*, which emphasizes a change in social identity and relations rather than acquisition and internalization of knowledge. Knowledge is, in this view, not something to be internalized, but something that is essentially relational and social. Some of the key components that contribute to this model of situated learning are described in the following paragraphs.

Identity and Membership. Identity and membership are concepts that provide two perspectives on essentially the same phenomena – identity is expressed and developed in terms of group membership. Wenger (2010) noted that "membership" can be expressed in various sometimes subtle or indirect ways, including through *participation* in shared activity, *imagination* facilitated by engagement with cultural artifacts, or through *alignment* of activities and practices with a perceived cultural norm.

Reproduction. Learning is a process by which newcomers become old-timers, and are changed through this transition: "learning thus implies becoming a different person" (Lave & Wenger, 1991, p. 53). An outcome of this process is that the community is reproduced and renewed. Recognizing learning as a mechanism of social reproduction carries with it the potential for critique, as it exposes how established hierarchies of power renew themselves through education that expresses *symbolic violence* (Bourdieu & Passeron, 1990).

Periphery and Centre. Identity and membership do not entail a static binary between insiders and outsiders but represent a changing relationship between individuals and how they perceive and are perceived in terms of the group. Learning is the process of moving from the periphery of a group to its centre, and it is the recognition (by both those at the periphery and centre) of certain forms of legitimate peripheral participation that identifies individuals as learners. The periphery is a place where one is prevented from participating fully, the centre represents a place of full participation, and legitimate peripheral participation lays out a learning pathway. This pathway has "ambiguous potentialities" (Lave & Wenger, 1991, p.36), as being held at the periphery of participation, while potentially holding out the promise of eventual inclusion, is inherently a form of exclusion and disempowerment.

Transparency. Legitimate peripheral participation is often marked by increased access and use of the technologies (in the broadest sense) of the practice. The use and significance of these practices "may be more or less *transparent* to learners" (Lave & Wenger, 1991, p. 102), in a dual sense: the technologies of practice are transparent when they are used fluidly and naturally, and, in a different way, they are transparent when their relevance and significance are not obscured. The transparency of technologies used in practice in part determines the opportunities available to learners to become full practitioners (Lave & Wenger, 1991, p. 123).

Discourse of Practice. As noted by (Lave & Wenger, 1991), "issues about language . . . have more to do with legitimacy of participation and with access to peripherality than they do with knowledge transmission" (p. 105). Adopting the particular speech that is used by full participants is central to assuming the identity of a full participant. A distinction can be drawn between speech *about* practice (how practice is discussed and related through stories), and speech *within* practice (the forms of discourse used within the practice itself). The use of both external and internal forms of discourse can mark the transition from peripheral to full participation within communities of practice.

Legitimacy. *Authenticity* is an intrinsic value that is derived from the source or origin of an entity or practice, while *legitimacy* is an extrinsic value sanctioned by authority or acquired through conformance to established norms. In idealized applications of situated learning, it is understood that peripheral participation should include authentic activities that are consistent with actual practice (Brown et al., 1989). While estimations of legitimacy and authenticity may coincide, it is also possible that they do not: activities that are considered legitimate may not represent authentic practice, and some authentic practices may not be recognized as legitimate. A disparity between authentic and legitimate activities may bring learning claims made about the community

of practice into dispute.

Affinity Spaces

In the *affinity space* model (Gee, 2004) of situated learning, participants are seen primarily as individuals motivated to engage by their interest in a topic. The *affinity space* is a (possibly virtual) meeting place for the brokering of these individual interests and for working together on common projects. Lammers et al. (2012) notes that affinity spaces are primarily defined by "common endeavor" and that "participation is self-directed, multifaceted and dynamic" (p. 48). Affinity spaces are generated and sustained by individuals interacting with and generating content in which they share interests. As stated by Gee (2017), "affinity spaces are primarily defined by an affinity for solving certain sorts of problems" (p. 28). Some of the key components that contribute to the affinity space model of situated learning are described in the paragraphs that follow.

Spaces of Social Learning. In describing learning that comes out of highly motivated engagement with valued social practices, Gee (2004) argues that describing the space of interaction avoids pitfalls that attempts to describe a community of practice within that space are prone to. The word "community," in this view, carries with it inescapable connotations of strong ties that are not appropriate when describing online spaces. In these contexts, where degrees of membership are difficult to ascertain, it is more useful to describe the features of the space of interaction, rather than the characteristics of the group. Spaces are a place of interaction for people who see themselves as "free agents" who need to flexibly connect to multiple sources of experience in building a portfolio that allows them to succeed in the "new-capitalist marketplace" of contemporary society (Gee, 2004, p. 105).

Content and Knowledge. A semiotic space is a space composed of structured content: "To define any space we first need to start with some content - something for the space to be 'about'" (Gee, 2004, p. 80). However, an affinity space must provide more than static content – participants must be able to insert themselves into this space, modify and add to it. The content of an affinity space is dynamic and is transformed through interactions. An affinity space enables development and exchange of knowledge that can be *individual*, *distributed*, *dispersed* (outside of the space itself), and *tacit* (knowledge that may not be easily explicated but that is shared through joint action).

Portals and Generators. A *generator* is a source of content for an affinity space, for example "in a cooking club, the cookbooks and shared recipes are generators" (Gee, 2004, p. 80). Gen-

erators may be *strong* or *weak*, depending on how effectively it generates content. A *portal* is a feature of an affinity space that provides access to the space. Generators may be portals (an accessible textbook generates content and provides access), but not necessarily (a teacher's manual that is not available to students generates content but not access). Some portals can be strong generators, in that the means of accessing the space and interacting within it is an effective way of generating content (Gee, 2004, p. 85).

Specialist Language Varieties. Learning about a certain topic entails learning to communicate in a specialist variety of language that may be quite different than the vernacular learned at home and used outside of specific contexts. What we speak about and how we speak about it are inseparably linked, as noted by Gee (2004): "content is accessible through the specialist variety of language, and in turn, that content gives meaning to that form of language" (p. 18). Struggles with traditional schooling can in part be traced to difficulties in learning the academic specialist varieties of language associated with school subjects. Affinity spaces, particularly those associated with "modern technologies and media" can provide more compelling and motivating venues for expression in specialist varieties of language than traditional schooling (Gee, 2004, p. 38).

Shifting and Strategic Identity. Participation in an affinity space is not predicated on aspects of identity such as "race, gender, age, disability, or social class," but such identity can be disclosed and used "strategically" (Gee, 2004, p.85). In the canonical examples of affinity spaces (online forums), this back-grounding of obvious markers of identity is accomplished through the anonymity that such forums afford. Learning is a process of developing an identity, affinity spaces provide contexts where "shape shifting portfolio people" can learn the rules of the game of a particular identity, and an aspect of participating in that space is the option of leaving behind other aspects of identity. Learning in affinity spaces means taking on different identities across spaces and while interacting within a space (Gee, 2004, p. 111–113).

Games and Simulations. Gee (2004) asserts that learning anything is "about learning the right moves in embodied interactions in the real world or virtual worlds, moves that get one recognized as 'playing the game': that is, enacting the right sort of identity" (p. 48). Preparing for action and sense-making within these enacted identities requires a process of internal simulation building, where learners construct and imagine acting in model "games of the mind" (Gee, 2004, p. 51). With this understanding of learning, participating in actual or virtual games and simulations can be understood as providing essential learning opportunities.

Differentiating Community of Practice and Affinity Space models

The community of practice and affinity space models share much in common in starting from the core tenets of situated learning but vary considerably in their elaboration of these shared principles. Both models attend to distributed models of knowledge and emphasize social aspects of learning, but offer distinct interpretations of the roles of identity and membership, and point to different sources of legitimacy.

The affinity space model focuses on features of the learning context that provide access to interaction and facilitate content creation, which are essential in attracting the attention of individual interest. The interest that individuals express towards the shared projects that they work on is the source of legitimacy in the affinity space model (Gee, 2004), a space that neither requires nor recognizes overt signs of membership. The perspective of communities of practice looks at processes of individual and community change, how newcomers obtain mastery in a practice, gain more full membership and eventually replace the old-timers in a process of community renewal. The sources of legitimacy in this model include the adherence to cultural conventions and the roles performed by the old-timers (Lave & Wenger, 1991). In the following section, features of Twitter discourse will be identified that may potentially highlight the different interpretations these models offer.

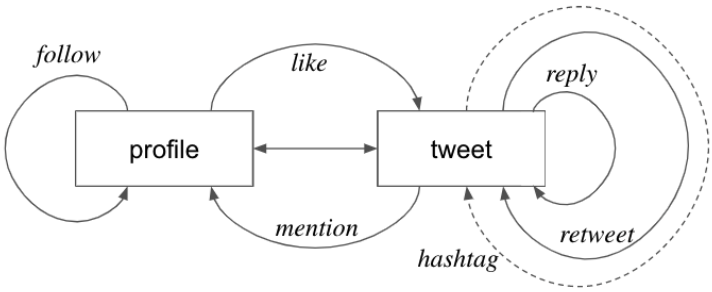
Twitter Discourse

As noted in previous chapters, the phrase *Twitter discourse* is used in part to highlight how interactions on Twitter can sometimes blur the distinctions between text and talk, and how such interactions also involve *non-textual* elements. The non-textual aspects of Twitter discourse are expressed through various affordances and conventions that act in a way similar to paralinguistic cues in spoken language to convey metameanings (Sheldon et al., 2019; Tannen, 2013).

Twitter exchanges are made up of both content and metadata that form a particular social discourse: *profiles* are text, hypertext, and images that represent a speaker, *tweets* or *statuses* are presented as utterances, indicators such as *replies*, *retweets*, *mentions*, and *hashtags* are presented as orientations for those utterances, while *likes* and *follows* are presented as social signals of favour or disfavour. Hashtags are identified as key components of this discourse, functioning both as content (they are text within tweets and profiles) and metadata; these are recognized within the framework as a means of identifying the "topical conversations" which contribute to teachers' informal professional development. Twitter discourse includes not only tweet content, but also performative elements and indicators of legitimacy that are captured as data and metadata and presented to participants. Performative aspects of Twitter communication include whether a tweet is a *reply*, *retweet*, or *direct tweet*, how it incorporates *mentions*, *hashtags* or other conventional

or idiosyncratic content, as well as the content of user profiles to which tweets are linked. Tweet metadata such as *likes* and *reply* counts, and profile metadata, such as *follower* and *friend* counts, are possible indicators of legitimacy that form another aspect of Twitter communication.

Figure 3.1
Twitter Content and Metadata



The content of tweets (textual and non-textual), associated profiles, and additional data and metadata together provide the immediately observable aspects of the discourse within which meaning is expressed on Twitter. A simplified view of the relationships that exist among content and metadata on Twitter is shown in Figure 3.1; these components and their interactions form the observable aspects of the discourse within which meaning is expressed on Twitter. In Figure 3.1, the primary textual content of profiles and tweets are shown as entities (rectangles) and information about the relationships between these entities (lines and arrows between rectangles) is often revealed through metadata. The relationships shown in Figure 3.1 include:

- A profile can *follow* another profile. In Twitter, following is an asymmetrical relationship. The profiles that follow a given other profile are the *followers* of that profile, the profiles that a given profile follows are called its friends.

- A profile can *like* a tweet. Tweets can have any number of likes attached to them, and profiles can like any number of tweets.

- A tweet may *mention* a profile by including the profile handle in the body of the tweet. Because the mention is embedded in the body of the tweet, the number of mentions in a tweet is limited. Mentions are an example of inline metadata – they are both content and metadata.

- A tweet may be a *reply* to another tweet. Replies allow tweets to be threaded into "conversations" or (when self-replying) into longer posts.

- A tweet may be a *retweet* of an existing tweet.

- A tweet may contain *hashtags*, formed by adding the hash symbol in front of a sequence of characters. Like mentions, hashtags are an example of inline metadata, and the number of hashtags is limited because they are embedded within the body of the tweet. In Figure 3.1 the hashtag is shown as a partial relationship between tweets, as they can function as an indirect way to point to other tweets that share the same hashtag.

The stream of Twitter data is not structured by pre-defined categories but receives its form based on algorithms that take input (in undisclosed ways) from choices made by those who tweet and those who interact with tweets. The digital traces of these choices are expressed as metadata. Much of our understanding of how Twitter data is presented, viewed, and interacted with comes from analyzing the metadata associated with it. When attempting to understand what is happening with a set of tweets, the content of the tweets, which may be textual or multimodal, may be of secondary importance to the metadata associated with them.

Features of Twitter Discourse

All social discourse presents a dichotomy of being simultaneously "a medium for participation in the same culture," while also providing individuals with "a medium for transmitting intentional experiences" (Habermas, 2002, p. 125). Communities of practice and affinity spaces present models of situated learning that fall on either side of these different perspectives on discourse. Simplifying the distinction between the two models, a perspective based on communities of practice would attend to features of discourse that demonstrate the dynamics of identity development within a shared culture, while the affinity space model would look at features that show how individuals come together over topics of mutual interest. Appreciating that the community of practice model is more concerned with *identity* of participants and affinity spaces with the *topic* being discussed helps to identify which aspects of Twitter discourse require particular attention. Attending to features that indicate aspects of identity and topic should present opportunities to explore the differences and similarities offered by these two models of situated learning. The following paragraph describes several features of Twitter discourse that have the potential to tell us about the topics discussed and the identity presented by the participants in the discourse.

Hashtags Used. Used and interpreted in a variety of ways, hashtags stand out among other elements of Twitter discourse for their ambiguity, but also for their usefulness in understanding both social interaction and individual intent. Ostensibly content markers, the folksonomic nature of hashtags means that their use is socially negotiated, often revealing more about the individual using the tag than about the content that is tagged. In this way, hashtag use speaks both to identity and topicality.

Tweet Content. The text that is included in a tweet is generally taken as the primary "content" of the discourse, which is given metameaning by other factors, some of which are captured in metadata. Despite the levels of metameaning that may be providing subtext, generally, it is tweet content that provides the apparent topic. Analyzing the terms used in tweet content can allow us to classify a tweet as on or off-topic, and can help identify topical themes in Twitter exchanges. In addition, the content of a tweet may be used to disclose user identity, either directly (naming professional and personal interests) or indirectly through term usage.

Discursive Style. Zappavigna and Martin (2018) note that Twitter discourse "displays features of monologue, dialogue and broadcast communication, despite often simply being termed a form of public 'conversation'" (p. 6). While a participatory (or conversational, or dialogic) style has been interpreted as a sign of identity development and reflection (Hawkes, 2006), the use of a broadcast style is seen as "identity projection" (Page, 2012). Identifying the discursive style can, in part, be accomplished by looking at the formal features of the discourse (grammatical and structural aspects, rather than individual words or meanings). Participatory talk is marked by *involvement strategies* such as the use of questions and direct addressing (Hawkes, 2006; Tannen, 2013), while broadcast talk can be indicated by more frequent use of hashtags and fewer interrogative statements and greater use of declarative or imperative clauses (Page, 2012).

Value Expression. Social affiliation is frequently demonstrated through an expression of shared values. While it may be difficult to identify specific values expressed and identified within a large discourse corpus, linguists have identified formal markers that indicate a general unspecified expression of value. Zappavigna and Martin (2018) note that hashtags can be used to emphasize key terms that express shared values, while (Tannen, 2013) remarks that repetition (of phrases, words, letters) can be a mark of intensity and enthusiasm. Formal aspects of hashtag use and repetition may provide indicators of *value expression* and consequently of social affiliation. The same features of repetition and emphasis also indicate the topic of the tweet – a topic that the user identifies with and possibly draws personal meaning and social affiliation from.

Profile Content. The Twitter profile provides an opportunity for an optional personal statement. Teachers frequently use the Twitter profile to describe aspects of their professional, and to a lesser extent personal, identity (Carpenter et al., 2019). The level of interest that a user has in a particular topic, and their identification with an education-related profession, may be indicated by specific terms in their Twitter profile. Profile text is used to reveal aspects of identity, and can also be used to declare topics that users affiliate with.

Engagement. Twitter metadata offers several metrics of engagement that are digital traces of how users respond to the profiles and the tweets of other users. Some of these engagements include likes, retweets, and replies, along with friend (someone a user follows) and follower counts. Levels of engagement may be associated with concepts such as reputation, participation level, usefulness, topical relevance, or social/symbolic capital. One measure of engagement that attends to profile metadata rather than tweet metadata is the *reputation* index (Mccord & Chuah, 2011; Wang, 2010) that can be assigned to a profile.

$$R(p) = \frac{n_I(p)}{n_I(p) + n_O(p)} \tag{3.1}$$

In Equation 3.1, the friend–follower directed graph of the profile p is considered, with friend relationships of a profile considered as "outgoing" edges and counted by $n_O(p)$ and follower relationships with the profile considered as "incoming" edges counted by $n_I(p)$. Reputation score, $R(p)$, is a ratio between the incoming edge count and the sum of the incoming and outgoing edge counts. A *spam profile* is expected to be following many other profiles while having few followers itself (Grier et al., 2010), so will consequently have a reputation that approaches zero. A profile that is followed by many but follows few would have a reputation closer to one, conforming to the expectations of a trusted source or celebrity profile. A completely reciprocating profile that follows another profile if and only if that other profile follows it back would have a reputation score of one-half.

These features of Twitter discourse that attend to identity and topic are of particular interest when looking at the phenomena of Math Teacher Twitter from the perspective of situated learning. When identifying these features, it is important to be aware of the common tendency toward *reification*. Not only does applying everyday terms to these features make them seem more real, but the use of terms like "reputation" (and, of course, terms like "friend") are potential examples of *concept displacement* (Schön, 1963) where the application of a metaphorical term for a new concept can lead to a change in how we think about the original term that is being used metaphorically. The use of real-world social concepts to describe the constructed online environments is possibly both a symptom and cause of how strongly the reality of the Twitter environment is perceived by some.

Situated Learning in the Twitter Environment

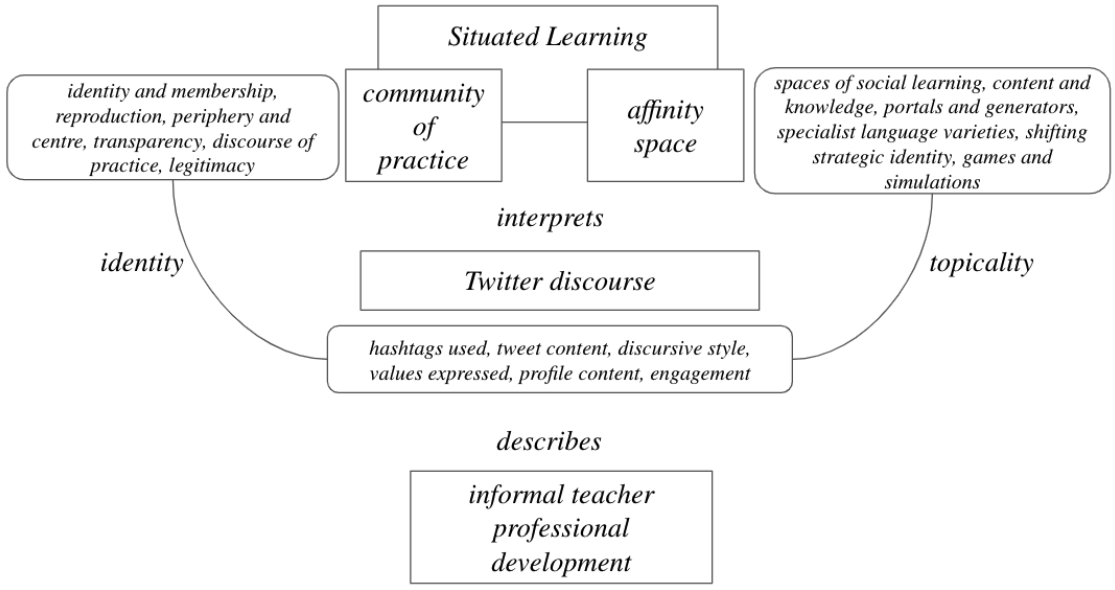
In the analysis of this study, features of Twitter discourse will be interpreted using the identified components of the community of practice and affinity space models. This proposed analysis raises a key question: Is it valid to apply models of situated learning to Twitter discourse at all? Theories of situated learning assert that knowledge is *embodied* and that learning occurs in the context of *authentic* social experience (Brown et al., 1989). Given this perspective on knowledge and learning, it is reasonable to ask whether online communication using Twitter provides a social situation in which knowledge exists and learning can occur. Dall'Alba and Barnacle (2005) and Kekki (2020) have argued that participatory media environments can indeed meet this threshold of sustaining distributed knowledge and providing the opportunity for authentic interactions for learning. Other research has noted that there are caveats and cautions that should be applied when making assumptions about the social context provided by participatory media.

One problem that presents itself is that the universality of the experienced reality of online interactions is disputed. Clark and Green (2018) contend that the authenticity of online interactions is not uniform and depends significantly on the attitudes of participants: individuals who have a strong belief in the reality of online interactions are more willing to participate in ways that build online relationships, which leads to a more positive evaluation of the outcomes of those interactions. The perceived reality of the Twitter environment is uneven, where different participants, or participants at different times, have varying senses of the reality of the engagements they are having.

Considering the Twitter environment as a viable space for interactions and learning involves confronting the "thorny problem of indicators" (Star, 1999, p. 387), an essential difficulty in the study of digital infrastructure. While the Twitter environment may be considered as a particular form of social reality in itself, it may also be considered a record for digital traces of activity that should be more properly located within a larger external reality. When applying models of situated learning to the Twitter environment, larger contexts of the activities and motivations of participants may at times need to be considered in addition to the observed interactions within the platform.

While acknowledging the difficulties of applying these concepts together within this context, this study integrates models of situated learning and ways of understanding features of Twitter discourse as a means of generating descriptions and interpretations of informal teacher professional development on Twitter, as illustrated in Figure 3.2. In this framework, the identified features of Twitter discourse are used to create a description of the informal professional development of mathematics teachers (in response to RQ1), and these descriptions are interpreted using the identified components of the affinity space and community of practice models of situated

Figure 3.2
Conceptual Framework



learning (in response to RQ2). In keeping with the different approaches taken by these two models, when viewing Twitter discourse through the lens of communities of practice, attention is paid to Twitter discourse features that highlight *identity*, while applying the affinity space perspective, emphasis is placed on those features that relate to *topicality*.

Chapter 4

Methods:

Locating and Exploring Math Teacher Twitter

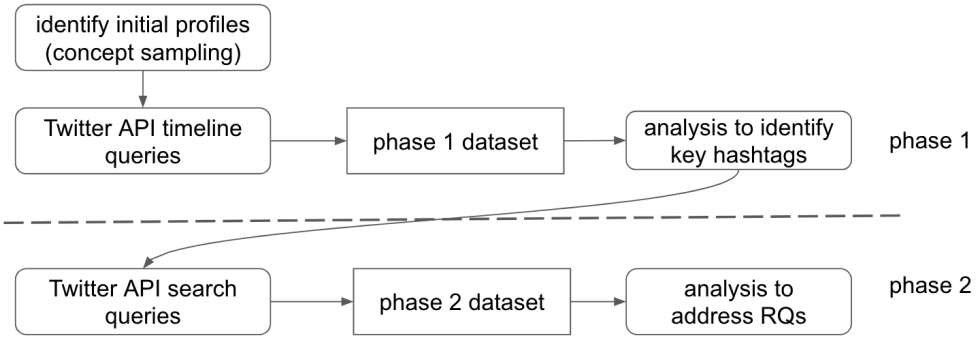
In this chapter, I will describe the methods that were used to obtain and analyze Twitter data in response to the research questions described in Chapter 1:

> *RQ 1: What are some of the important characteristics of the discourse associated with mathematics educators' informal professional development on Twitter?*
>
> *RQ 2: How do theories of situated learning, such as the community of practice and affinity space models, help us understand the informal professional development practices of mathematics teachers on Twitter?*

In answering these questions, following a number of studies described in the literature review of Chapter 2 (for example: Greenhalgh et al., 2016; Rosenberg et al., 2016; Staudt Willet, 2019), this study used hashtag-based queries of the Twitter API to build a corpus of tweet data that was then analyzed using software methods. However, the focus of the research questions on Math Teacher Twitter presented a problem for this hashtag-based approach: which hashtags should be used? To address this preliminary problem, the data acquisition and analysis were pursued in two phases: *phase-one* involved identifying profiles and acquiring data that would, through methods described in this chapter, allow for the identification of *key Math Education Twitter Hashtags*, while *phase-two* involved using these hashtags to acquire the tweet corpus to be analyzed to answer the research questions. Consequently, there are two data sets in this study: the preliminary *phase-one dataset* consisting of tweet and profile data for selected profiles, and the *phase-two dataset* consisting of tweet and profile data obtained from hashtag-based queries (see Figure 4.1). After a general description of the structure of Twitter API data, this chapter provides an overview of the methodological problems that are addressed by the two-phased approach taken in this

study. The methods and results of phase-one are then described, leading to an overview of the acquisition of the phase-two data and methods used to analyze it.

Figure 4.1
Phases in Data Acquisition and Analysis



Twitter API Data

The source of data for this study is public content obtained from Twitter obtained using the Twitter API (Twitter Inc., 2019). The Twitter API is a publicly accessible application programming interface that allows data from Twitter to be acquired and processed using a variety of software methods. This allows data to be obtained from Twitter systematically and facilitates querying and analysis through software methods. The **rtweet** package (Kearney, 2019), which allows data from the Twitter API to be acquired and processed within an R (R Core Team, 2020) programming environment was used for data acquisition and initial processing. Data cleaning and subsequent analysis were completed using R. Python (van Rossum, 1995) and LaTeX (Lamport, 1994) language scripts and documents were developed and used for further processing, analysis, and presentation.

As described in Chapter 3, Twitter discourse is made up of data and metadata, and the Twitter API makes much of this available through the query interface that it exposes. The Twitter API returns for each tweet a list of 90 attributes, many of which are unused for a given tweet (the attributes are for fields that are unavailable or not applicable). These attributes include the content, information about media included with the tweet, information about the original tweet (if it is a retweet or quoted tweet), and information about the profile that authored the tweet. A summary of some of the key attributes returned by the Twitter API is provided in Table 4.1.

Derived measures, such as the *reputation index* defined by Equation 3.1 can be calculated using combinations of the attributes in Table 4.1 (for the reputation index, the `followers_count` and the `friends_count` provide $n_I(p)$ and $n_O(p)$, respectively). Methods for ascertaining other features of Twitter discourse outlined in Chapter 3 are described later in this chapter.

Table 4.1
Selected Attributes Provided by the Twitter API

attribute	description
`user_id`	A unique identifier for the Twitter profile.
`status_id`	A unique identifier for the tweet.
`text`	The textual content of the tweet.
`is_retweet`	A boolean indicating if the tweet is a retweet.
`favorite_count`	The number of "likes" received.
`retweet_count`	The number of retweets of the tweet.
`hashtags`	A list of hashtags included in the tweet.
`mentions_user_id`	A list of users mentioned in the tweet.
`followers_count`	The number of followers of the profile.
`friends_count`	The number of profiles followed by the profile.
`statuses_count`	The number of tweets issued by this profile.
`description`	The profile text.

Rationale for a Two-Phased Approach

Following several of the studies described in Chapter 2, Twitter hashtags were used in this study as a means of gaining access to a portion of the Twitter discourse around mathematics education and mathematics teacher professional development. In the absence of a defined subject classification system, Twitter hashtags have been identified as an affordance used by educators for finding and participating in topical exchanges, as noted by Carpenter et al. (2019):

> Hashtags appear to play an important role in educators' Twitter use by facilitating initial connections and ongoing conversations between geographically dispersed educators who share common interests and/or goals. (p. 2)

However, because hashtag-based organization represents a "folksonomy" (Vander Wal, 2007) evolving through use and interaction rather than a taxonomy that obeys standard (or easily identified) topical boundaries, uncovering relevant hashtags for a specific domain such as Math Teacher Twitter presents a problem. The problem of finding Twitter conversations about mathematics education is common to educators wishing to engage in Twitter-based discussions about mathematics education and to researchers who wish to study these discussions. In this section, three aspects of this overall problem are identified: *the vocabulary problem*, *the problem of under participation*, and *the problem of predetermination*.

The Vocabulary Problem

Fu et al. (2010) notes that social tagging systems can suffer from a *vocabulary problem*: because users are free to choose any hashtags to describe their tweets (or general resources in

other systems) attempts to retrieve information will be impeded by an ever-increasing diversity of tags used to describe the same type of resources. Research in the area of social tagging (across a variety of platforms) has indicated that the vocabulary problem does not necessarily lead to a complete collapse of information retrieval through tags because "emergent structures" develop within tag usage leading to meaningful organization and stable usage among the hashtags associated with a particular topic (Fu et al., 2010; Golder & Huberman, 2006). Unfortunately, because the structures that do emerge to make (more or less) consistent tagging possible do not necessarily follow a particular convention, these hashtags are *inside knowledge.* Researchers are, in general, forced to rely on inside knowledge of some kind when looking at more narrowly defined domains of teacher professional development on Twitter. In investigating hashtags beyond the widely known `#edchat`, Rosenberg et al. (2016) relied on previously published lists of "State Education Hashtags" and Greenhalgh et al. (2016) relied on familiarity with the particular education program they were investigating. As these examples illustrate, investigations of specific aspects of teacher professional development on Twitter require a way of obtaining and validating the insider knowledge of appropriate hashtags in order to respond to the vocabulary problem that folksonomic hashtag use presents.

The Problem of Under-participation

One possible strategy for observing Twitter interactions concerned with math education and math teacher professional development would be to identify a group of math teacher profiles (followers of `@nctm` for example), observe their tweets, and extract common hashtags used by these profiles. Unfortunately, this strategy runs up against what is commonly referred to as the *one-percent rule,* with the result being that even within an identified group, very few interactions will be on topic when observed at the group level.

The one percent rule expresses the observation that a few people are responsible for most of the relevant content and participation in any online group, asserting (as a heuristic) that one percent of identified group members are responsible for most content, a further nine percent generate the remaining content, while 90% of group members participate as passive observers (lurkers) only (Carron-Arthur et al., 2014). The essential applicability of the one-percent rule has been validated in studies of internet support groups, and has been accepted as a general principle of internet marketers (Carron-Arthur et al., 2014; Van Mierlo, 2014).

Attempts to access content related to math education and math teacher professional development from community members directly would require first identifying *superusers* and *contributors* who make up roughly 10% of identifiable math teachers on Twitter who are visibly engaged in professional development activities.

The Problem of Predetermination

Several studies have looked at the use of particular education focused hashtags in the context of their role as facilitators of informal teacher professional development, such as `#edchat` (Britt & Paulus, 2016; Gao & Li, 2017; Staudt Willet, 2019), regional education hashtags (Greenhalgh et al., 2018; Rosenberg et al., 2016), or other course-specific hashtags (Greenhalgh et al., 2016). Starting with a known hashtag seems a reasonable response to addressing the vocabulary problem. However, querying for tweets associated with a known hashtag or set of hashtags may artificially limit the scope of the data obtained. A query based on a hashtag will return a defined/closed set of tweets that perhaps represents an incomplete fragment of the hashtag-mediated interactions around that topic. Actual practice in Twitter communications around a particular topic may involve multiple hashtags that are used in different contexts, and starting with a specific hashtag will not only omit certain tweets, but may also neglect some aspects of differentiated hashtag use for a given topic.

A Two-Phased Solution to Identifying and Using Hashtags

One approach to addressing the vocabulary, under-participation, and predetermination problems is to start with a small sample of identified profiles that are known or expected to participate in Math Teacher Twitter and observe from that sample the common hashtags used by these profiles. This initial profile set should form a broad selection of *contributors* (if not *superusers*) and should include a differentiated selection of profile types in order to mitigate bias. Choosing this initial set of profiles is a form of *concept sampling*, where "the researcher samples individuals or sites because they can help the researcher generate or discover a theory or specific concepts within the theory" (Creswell & Guetterman, 2019, p. 208). This approach, while still relying on insider knowledge, relies on less specific insider knowledge than knowing which specific hashtags to use. One step back from presupposing relevant hashtags directly, inferring these from the use of a set of initial profiles relies on more diffuse insider knowledge that allows for a level of validation of the set of hashtags that will be used. By discovering key hashtags used in Math Teacher Twitter using a set of initial profiles, the vocabulary problem is avoided, the problem of under-participation is acknowledged, and the problem of predetermination is addressed.

Adopting this approach to identifying hashtags prior to using them to build a corpus of tweets to answer the research questions, as noted previously, involved following a two phase process. In phase one, an initial set of profiles was selected and queried to create the phase-one dataset, from which key Math Education Twitter Hashtags (METHs) were discovered and used to create the phase-two dataset – a set of Twitter data representing a corpus of Twitter discourse investigated to answer the project's research questions. Table 4.2 provides a simplified description

of the data acquisition steps in these phases.

Table 4.2
Phases, Simplified Example Queries, and Resulting Datasets

phase	example queries	application	result
one	`get_timeline('nctm', n=1000)`	Applied over a set of selected profiles.	**phase-one dataset**: A set of tweets and profiles used to identify key METHs
two	`search_tweets('#math', n=1000)`	Applied over a set of key METHs over an extended time period.	**phase-two dataset**: A corpus of tweets analyzed in response to RQ1 and RQ2

Phase-one Methods and Analysis

To obtain the initial phase-one dataset that allowed the identification of hashtags to be used in acquiring the phase-two dataset, a set of initial profiles was identified. The tweets from these profiles were deemed likely to lead, through the hashtags they use, to the important sources of relevant conversations on Twitter. These profiles include a set of Twitter profiles of mathematics teacher *associations* (five profiles), profiles associated with several *initiatives* whose goals include improving mathematics teaching (five profiles), a set of resource and professional development *providers* (five profiles), and a set of teacher profiles of *teachers* known to be active on Twitter (10 profiles). For these 25 profiles, profile information, tweets, and tweet metadata were obtained from queries for one thousand recent posts; 23217 posts were returned and processed. Table 4.3 summarizes some of the high-level characteristics of this profile and tweet data; in this table and others, teacher profiles are listed as anonymous.

Associations Associations that support the professional development of mathematics teachers seem likely candidates for profiles that will attempt to engage with mathematics teachers on Twitter. Associations included in this initial set of profiles includes the National Council for Mathematics Educators (`@NCTM`), The Nova Scotia Mathematics Teacher Association (`@MTA_NS`), the Ontario Association for Mathematics Education (`@OAMEcounts`), British Columbia Association of Math Teachers (`@BCAMT`, and the Saskatchewan Mathematics Teachers Society (`@SMTSca`).

Initiatives There are several professional development initiatives that focus on providing support to mathematics educators and that are active on Twitter. The initiatives included in the set of initial profiles include the Global Math Department (`@GlobalMathDept`), Open Middle

(@OpenMiddle), Math Teacher's Circle (@MathTeachCircle)[1], NCTM Illuminations (@NCTMIllum) and TODOS (@todosmath). These initiatives vary significantly, and includes initiative sponsored by associations, non-profits, and groups of individual mathematics teachers.

Providers Professional development providers that focus on mathematics education engage with mathematics teachers and are also likely to make use of hashtags to reach that audience. The professional development providers included in the set of initial profiles include Make Math Moments That Matter (@MakeMathMoments), Let's Play Math (@letsplaymath), YouCubed (@youcubed), Desmos (@desmos), and Illustrative Mathematics (@illustrateMath). These providers range from single individuals who provide resources and professional development, to medium sized companies specializing in mathematics professional development and curriculum.

Teachers Included in the group of initial profiles are ten identified mathematics teachers who are active on Twitter. This set includes Canadian and American math department head teachers, teachers who have spoken at professional development conferences, and teachers who maintain blogs dedicated to mathematics education. While the Twitter profiles of these teachers are public, unlike the associations, initiatives, and providers included in the initial profile set, the profile names of these teachers have been redacted.

Tweet and Profile Analysis

Using the Twitter API get_timeline query, each profile in the set of 25 initial profiles set was queried for its last (up to) 1000 tweets. The combined set of 23,217 tweets and associated tweet and profile data formed the phase-one dataset. Table 4.3 provides some characteristics of each profile. One notable characteristic is the percentage of tweets that are retweets. Retweeting (in the context of hashtags associated with professional development), was associated by Greenhalgh and Koehler (2017) with "knowledge brokers" who allow practitioners to connect with "knowledge creators". Another readily available measure is the *reputation* score (see Equation 3.1). The high reputation scores are not surprising for profiles that were specifically identified as trusted sources of information, and the (relatively) the lower scores for certain profiles may indicate a concerted effort on the part of the administrators of those profiles to "follow back" those who follow them.

To get a rough picture of the content of the tweets from the phase-one dataset, the most frequent terms were extracted from the tweets of each grouping (Table 4.5). This high-level view of the content shows that *math* (a term that includes words such as mathematics, mathematicians,

[1] At some time prior to December 2021, the @MathTeachCircle Twitter profile was deleted.

Table 4.3
Characteristics of Initial Profiles (Phase-One Dataset)

type	profile	total tweets	retweets	reputation	like av.	rt av.
associations	NCTM	998	40.8%	0.9813	18.973	9.394
	MTA_NS	874	81.8%	0.5551	3.836	1.874
	OAMEcounts	987	88.9%	0.9972	19.291	10.382
	BCAMT	642	57.9%	0.9405	3.578	3.715
	SMTSca	999	67.9%	0.9132	2.336	3.517
initiatives	GlobalMathDept	990	95.4%	0.9531	5.826	2.174
	openmiddle	729	58%	0.7339	12.559	5.634
	MathTeachCircle	986	61.4%	0.8501	2.908	1.063
	NCTMIllum	498	24.7%	0.9917	3.221	2.811
	todosmath	995	87.3%	0.8727	14.405	5.183
providers	MakeMathMoments	996	43.2%	0.7829	4.912	1.739
	letsplaymath	1000	8.9%	0.448	2.875	1.121
	youcubed	537	56.4%	0.9946	21.902	8.744
	Desmos	1000	30.4%	0.9757	11.602	2.267
	IllustrateMath	1000	20.4%	0.998	14.509	5.24
teachers	anonymous-1	1000	23.9%	0.6364	3.516	0.427
	anonymous-2	995	34%	0.9849	11.511	1.012
	anonymous-3	1000	37.9%	0.5686	2.741	0.195
	anonymous-4	1000	5.2%	0.6835	5.581	0.47
	anonymous-5	1000	41%	0.8595	2.107	0.231
	anonymous-6	994	30.8%	0.6931	5.493	0.887
	anonymous-7	999	12.3%	0.8658	4.025	0.372
	anonymous-8	1000	25.9%	0.9182	5.151	0.345
	anonymous-9	998	6.8%	0.5284	3.574	0.83
	anonymous-10	1000	5.7%	0.85	5.358	0.547

Table 4.4
Characteristics of Initial Profile Groupings (Phase-One Dataset)

type	total tweets	retweets	reputation	like av.	rt av.
associations	4500	67.8%	0.9813	10.793	6.288
initiatives	4198	70.6%	0.9531	6.679	3.19
providers	4533	29.3%	0.7829	9.412	3.06
teachers	9986	22.3%	0.6364	4.897	0.538

and maths) is the most frequently referenced term for each profile grouping, and that other frequent terms include ones explicitly related to teaching and learning (such as *teach*, *student*, and *learn*), to professional development opportunities (*nctm*, *conference*, *register*), and to resource sharing (*blog*, *post*). The most frequent terms used in tweets by each profile group are terms that could be reasonably associated with the professional development interests of mathematics teachers. None of the frequent terms are obviously off-topic, indicating that these profile groups are not consistently tweeting about topics outside of interest to mathematics teachers.

Table 4.5
Frequent Terms in Tweets by Initial Profiles (Phase-One Dataset)

profile group	term 1	term 2	term 3	term 4	term 5
associations	math	nctm	register	teach	conference
$n_{term} = 20647$	0.0324	0.0224	0.0178	0.0141	0.0135
initiatives	math	problem	teach	check	nctm
$n_{term} = 12912$	0.0305	0.0155	0.0098	0.0084	0.0074
providers	math	student	learn	blog	post
$n_{term} = 42539$	0.0383	0.0124	0.0123	0.0103	0.01
teachers	math	think	student	teach	make
$n_{term} = 83572$	0.0082	0.0074	0.0073	0.007	0.0059

n_{term} denotes the number of terms.
Terms which are also non-word hashtag names or Twitter handles have been removed.

Identifying Key METHs

Table 4.6 shows the frequency of hashtag use by each profile, the average number of hashtags used when hashtags are present, and each profile's three most frequently used hashtags. Hashtags used are an indicator of content, and the most frequent hashtags shown in Table 4.6 shows further indication that, along with the term frequencies listed in Table 4.5 that the content of the tweets from these profiles reflects a concern with mathematics education. The overall hashtag use data in Table 4.6 reflects the fact that hashtags are not always used, and the distribution of hashtag-use frequency across the different groups of profiles is consistent with observations made by Page (2012), that more "corporate" entities tend to use hashtags more frequently than "ordinary" users.

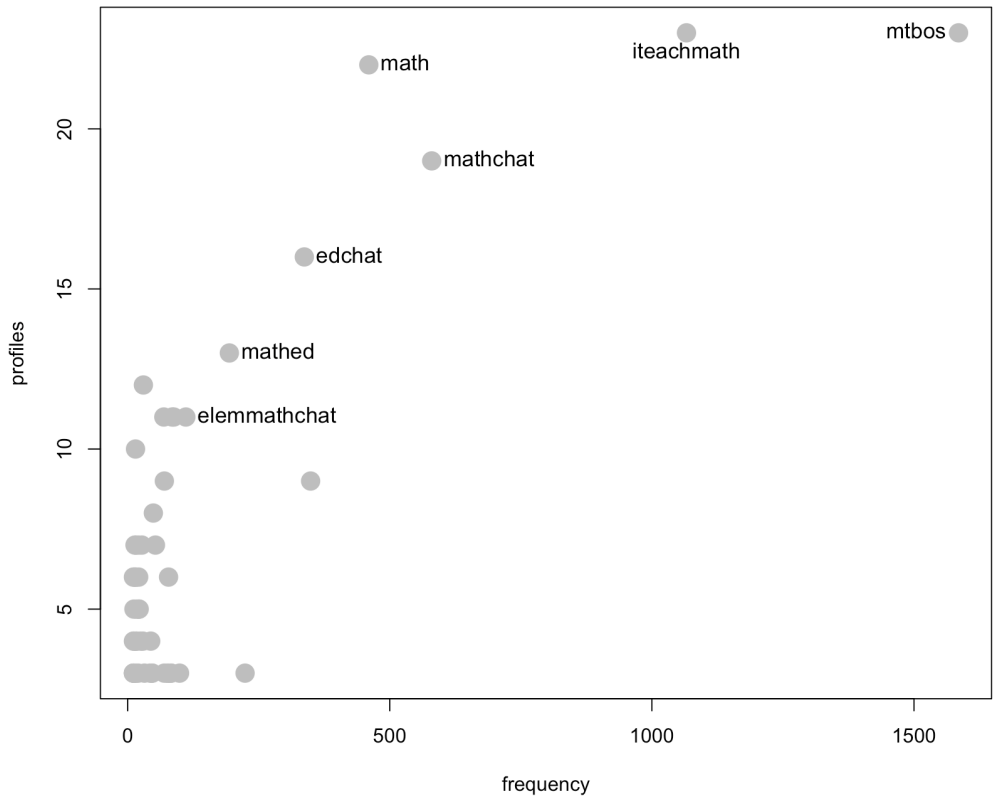
While a variety of hashtags are used by each profile, and many common hashtags can be identified, research into the vocabulary problem of hashtags cited above (Fu et al., 2010; Golder & Huberman, 2006) suggests that some stable usage and common structures should emerge, and that a common set of hashtags may classify the topical interests of Math Teacher Twitter. Among

Table 4.6
Hashtag Use by Initial Profiles (Phase-One Dataset)

type	profile	tag freq.	av. tags	top tags
associations	NCTM	0.745	3.118	nctm, iteachmath, mtbos
	MTA_NS	0.535	1.153	nsmta2017, nsmta2019, nsmta2018
	OAMEcounts	0.118	1.0	oame2017, oame2020, ontariomathsupport
	BCAMT	0.393	1.67	mtbos, weeklymathtasks, bced
	SMTSca	0.701	1.738	skedchat, mathchat, sum2017
initiatives	GlobalMathDept	0.565	2.308	gmdwrites, mtbos, iteachmath
	openmiddle	0.366	1.348	dok2, dok3, mtbos
	MathTeachCircle	0.333	1.268	nctmannual, givingtuesday, summermtc2020
	NCTMIllum	0.6	1.787	math, nctm, mobileedchat
	todosmath	0.786	2.636	mathequity, todos2021, mtbos
providers	MakeMathMoments	0.581	3.836	mathchat, edchat, mtbos
	letsplaymath	0.48	3.167	mtbos, homeschooling, iteachmath
	youcubed	0.333	1.962	polychallenge, youcubed, youcubedprize
	Desmos	0.083	1.069	desmoslive, desmosify, learnwithim
	IllustrateMath	0.653	1.285	learnwithim, imtalkingmath, nctmboston19
teachers	anonymous-1	0.102	1.462	mtbos, elemmathchat, iteachmath
	anonymous-2	0.129	1.941	remotelearning, edchat, mathchat
	anonymous-3	0.227	1.652	math, education, mathematics
	anonymous-4	0.076	1.208	mathsartmonday, maydala, geogebraart
	anonymous-5	0.273	1.174	elemmathchat, mathart, mathgame
	anonymous-6	0.141	1.361	mtbos, ipowersbc, vconhm
	anonymous-7	0.053	1.5	iteachmath, mtbos, mathart
	anonymous-8	0.138	1.578	mtbos, smit2020, mmgcimathfair2021
	anonymous-9	0.258	2.054	mtbos, apstats, iteachmath
	anonymous-10	0.081	1.513	thinkingclassroom, iteachmath, mtbos

the Math Education Hashtags found in use, these commonly used tags should stand out as *key* Math Education Twitter Hashtags. To identify key METHs, a *term document matrix* was constructed, where the documents were each profile's collection of tweets, and the terms were all hashtags used. The term document matrix allows for a two-dimensional frequency assessment, where the frequency of terms within documents can also be compared across documents. This two-dimensional comparison is illustrated in Figure 4.2. For each hashtag, the combined frequency of overall occurrence (x-axis) can be compared with the number of individual profiles in the phase-one dataset that use the hashtag. Of the METHs found in the dataset, four are identified as occurring the most frequently across the most profiles: `#mtbos`, `#iteachmath`, `#math`, and `#mathchat`. After these four hashtags, the next most broadly and frequently used hashtag is `#edchat`, acknowledged in several studies as one of the most popular hashtags used by teachers. It was determined to restrict the set of *key* METHs as the four hashtags that were observed to be more frequently and broadly used than hashtagedchat within the phase-one dataset.

Figure 4.2
Hashtag Profile Counts and Usage Frequency for Initial Profiles (Phase-One Dataset)



Validating the Choice of Key METHs

With broad use across profiles, the choice of key METHs is *overdetermined* in that the identified key METHs are frequently used across all profile categories. However, as suggested by Table 4.6, not all tweets by profiles included in the phase-one dataset used these key METHs, or even used hashtags at all. It makes sense to ask if the content of tweets shows any difference between those that use key METHs and those that do not. The *bag of words* method (described later in this chapter) was used to identify term frequencies for both Tweets that include key METHS (Table 4.7), and those that do not (Table 4.8). While sets of most frequent terms shows that math education related terms show up frequently in both tweets that contain key METHs and those that do not, the frequency of these terms is greater in the tweets that contain key METHs. The frequency counts of the most frequent terms in the tweets that do not contain key METHs are lower overall, suggesting a more diverse set of overall terms, and less topical focus. For example, in tweets that contained key METHs the term *math* is the most frequently mentioned by associations, with a frequency of 0.0498 (Table 4.7), in tweets that did not contain key METHs, the term *math* is still the most frequently mentioned by associations, but with a frequency of 0.0256 (Table 4.8).

Table 4.7
Frequent Terms in Tweets of Initial Profiles Including Key METHs

profile group	term 1	term 2	term 3	term 4	term 5
associations	math	nctm	register	teach	webinar
$n_{term} = 5782$	0.0498	0.0372	0.0178	0.0156	0.0142
initiatives	math	nctm	problem	register	lesson
$n_{term} = 1910$	0.0686	0.0194	0.0152	0.011	0.0105
providers	math	listen	homeschool	play	learn
$n_{term} = 9831$	0.0526	0.0232	0.0195	0.017	0.0112
teachers	math	teach	student	think	tip
$n_{term} = 6140$	0.0347	0.0106	0.0104	0.0062	0.0062

n_{term} denotes the number of terms.
Terms which are also non-word hashtag names or Twitter handles have been removed.

Table 4.8
Frequent Terms in Tweets of Initial Profiles Excluding Key METHs

profile group	term 1	term 2	term 3	term 4	term 5
associations	math	register	nctm	conference	teach
$n_{term} = 14862$	0.0256	0.0178	0.0167	0.0149	0.0135
initiatives	math	problem	teach	check	student
$n_{term} = 10908$	0.0241	0.0157	0.0104	0.0089	0.0074
providers	math	student	learn	blog	post
$n_{term} = 32552$	0.0342	0.0128	0.0127	0.0121	0.0117
teachers	think	student	teach	math	make
$n_{term} = 77286$	0.0075	0.0071	0.0067	0.0061	0.006

n_{term} denotes the number of terms.
Terms which are also non-word hashtag names or Twitter handles have been removed.

Methods for Phase-Two: Describing and Interpreting Twitter Discourse

Among all the hashtags used in the phase-one dataset four key METHs were found to have been used more frequently and across more profiles than any other hashtags. It was observed that tweets using these key hashtags showed more frequent topical terms in tweet content. These observations suggest that querying for tweets that use these key METHs provides a reasonable way to gain access to topical interactions on Twitter about mathematics education that have a wide range of participants.

The phase-two dataset was built by using independent queries for each of the key METHs between mid-October 2020 (2020/10/13) and early December 2020 (2020/12/05). The results of the queries were combined and filtered to produce a set of 9881 unique Twitter posts shared by 3133 unique Twitter profiles.

Describing Twitter Discourse

The first research question posed by this study is:

> *RQ 1: What are some of the important characteristics of the discourse associated with mathematics educators' informal professional development on Twitter?*

To provide an answer to this question, important features of Twitter discourse were identified in Chapter 3: *hashtags used, tweet content, discursive style, values expressed, profile content*, and *engagement*. This section outlines the methods applied to data in the phase-two dataset that

allow these features to be described. Methods used here are adapted from the evolving field of digital sociology (Marres, 2017), and from computational linguistics (Hawkes, 2006; Page, 2012; Zappavigna & Martin, 2018).

Hashtags Used

Some of the features of Twitter discourse described in Chapter 3 are directly obtained from attributes returned from the Twitter API. For example, the *hashtags used* are obtained from the `hashtags` attribute. In describing these, additional analysis can be applied to determine to what extent hashtags are co-occurring, and to assess other characteristics, such as their topical relevance. One measure of the co-occurrence frequency of each pair of hashtags is provided by the Jaccard index for the sets defined by these hashtags[2]. For two sets A and B, the Jaccard index $J(A, B)$ is a measure between 0 and 1 that indicates their level of co-occurrence, with 0 indicating no common elements and 1 indicating complete mutual overlap:

$$J(A, B) = \frac{|A \cap B|}{|A \cup B|}. \tag{4.1}$$

When frequencies of hashtags are compared, they have been observed to conform to *Zipf's law* (Zhu et al., 2018; Zipf, 1949) which expresses a more general observation concerning word frequencies within documents:

$$f = C \times r^{-1}. \tag{4.2}$$

Described by Equation 4.2 (where f is frequency, r is rank and C is a constant that is particular to the "document" being considered), characteristics of such term frequency lists are a steep drop-off from the most common terms and a long-tail of less common terms. The original theoretical explanation for the distribution of terms provided by Zipf (1949) is that in communication, as in other aspects of human behaviour, actors are compelled by "the principle of least effort" to use the most common and accepted terms when communicating.

Tweet content

Tweet content can be directly obtained from Twitter data from the `text` attribute (see Table 4.1). As noted, this textual content is primarily assessed in the current study using the *bag of words* or *vector space* method (McTear et al., 2016). The bag-of-words technique simplifies the content of the tweets by omitting common words (such as "and," "the," "of," etc.) and reducing *documents* to a collection of terms, where each term represents a set of stemmed words (the words *teach*, *teaching*, and *teacher* would all be represented by the term *teach*). The frequencies

[2]Another essentially similar measure is the *hashtag co-occurrence index*, described by (Fu et al., 2010).

of terms provide a high-level assessment of the topics expressed in the tweets associated with each hashtag. The bag of words method enables a word frequency-based analysis of language use that does not rely on parsing the grammatical structure of the text, or on machine learning techniques to classify the content. In addition to the bag-of-words method, searching for identified terms and hashtag use (where hashtags are taken as topical classifiers) were used to assess tweet content.

Discursive Style

Recall that the OECD description of the most prevalent form of informal teacher professional development is "informal dialogue to improve teaching" (OECD, 2009, p. 57). *Dialogue* is a specific kind of discourse that involves participation and exchange, and that this is particularly important in informal professional development, because this form of discourse is one that has the potential to promote reflection and identity formation (Hawkes, 2006). This *participatory talk* stands in contrast to the "identity projection" of *broadcast talk*.

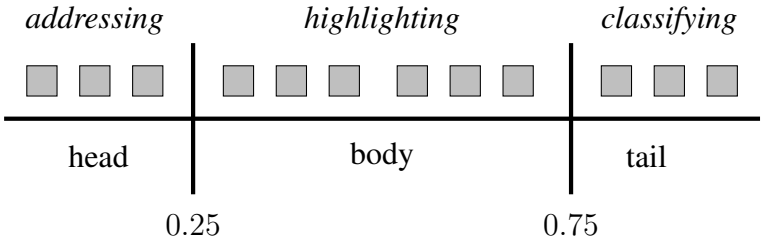
There are a number of formal indicators that can be used to assess discursive style. Participatory talk is characterized by addressivity (individuals and groups are directly addressed) and interrogative statements (questions are seen as eliciting answers from others), while broadcast talk usually involves lower levels of addressivity and interrogation, and more frequent use of hashtags.

Hashtag Placement and Addressivity. Hashtag placement is one indicator that can be used to assess addressivity. As "inline metadata" hashtags can be placed anywhere within a tweet, and the relative placement of a hashtag is one of the formal features which characterizes its use within a tweet. Placement of hashtags constitute "moves" in Twitter interaction and performance that can be seen as paralinguistic cues, used strategically or conventionally to overcome the loss of non-verbal queues available in face-to-face interaction. Hashtag placement can be seen as potentially contributing to the "metamessage" that frames the subtext of online interaction (Tannen, 2013, 2017).

Relative placement is something that can be assessed quantitatively, simply by treating the text of the tweet as a list of words and seeing where the hashtag sits in that list. For the purpose of assigning a general location within a tweet to a given hashtag, the tweet can be broken into three regions: the *head*, which is the first 25% of words, the *tail*, which is the last 25% of words, and the *body*, the middle section that takes up the remaining 50% of the words in the tweet.

While precise meanings cannot be ascribed to relative locations, linguistic and Twitter conventions suggest how placement of hashtags may indicate their function. Twitter convention is such that classifying tags, either idiosyncratic or folksonomic, are generally placed at the end of

Figure 4.3
Conceptualization of Hashtag Function and Position



a tweet, as a final statement of how it should be categorized, so tags that appear at the tail of the tweet are generally *classifying*. Corresponding to standard linguistic constructions of salutations, when a tag is placed at the head of a tweet, it is often seen as naming a group or entity to which the tweet is being addressed, consequently tags that appear at the head of the tweet are often indicators of an *addressing* function. Finally, when appearing within the body of a tweet, hashtags may be performing the role of *highlighting* a key word in order to draw attention to important ideas as well as potentially functioning as searchable text. Figure 4.3 illustrates the relationships between these functional roles and relative positions.

Interrogation and Participatory Talk. Participatory talk is identified by its employment of involvement strategies like direct addressing; another indicator of participatory talk is the use of the involvement strategy of asking questions (Hawkes, 2006; Page, 2012). In trying to assess which tweets may be employing an interrogation involvement strategy we can look at the occurrence of question words (what, when, why, how, who, and where), or for the presence of question marks as two purely "formal" identification methods.

High Frequency Hashtag Use. A marker of broadcast talk on Twitter is high-frequency hashtag use (Page, 2012). High frequency hashtag use has also been noted as a potential indicator of spam content (Carpenter et al., 2020), reflecting how spam falls under the more general category of *broadcast talk*.

Value Expression

Twitter hashtags are most often understood as an affordance that renders tweets *searchable* by topic, something that links disparate content from various sources together. Tweets that use searched-for hashtags find their way to audiences directly through searches or indirectly, being amplified by retweets, replies, likes and by other platform mechanisms that enhance visibility of posts that are interacted with. Linguistic studies of hashtag use have also identified how

hashtags perform functions within a tweet itself. Rather than exclusively acting as aggregators of content, hashtags have the ability to "operate as a linguistic marker referencing the target of evaluation in a tweet," amplifying values in the statement made by the text, and serve to "upscale the call to affiliate with values expressed in the tweet" (Zappavigna, 2012, p. 2). When used within the body of a tweet, the hashtag, according to Zappavigna (2012):

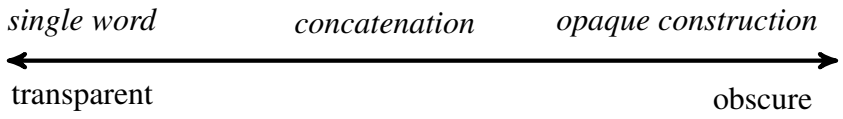
> . . . opens up the possibility of play with users creating tags that are unlikely to be used as search terms and which instead seem to function to intensify the evaluation made in the tweet. (p. 14)

Understanding hashtags as having a function *within* tweets rather than only *between* tweets helps to explain the use of hashtags which, either because of their ambiguity, obscurity or their overuse, do not seem to be relevant in the context of direct searches.

While hashtag placement at the front of a tweet can be taken as an indicator that it is being used addressively, hashtags within the body of a tweet can sometimes indicate that they are highlighting a key word (rather than acting as a topic classifier). Using placement, along with a measure of the *legibility* of the hashtag can help identify cases where hashtags are not being used primarily to enable search, but rather to highlight values.

Hashtag Legibility. Ranging from simple words to complex concatenations of contractions and acronyms, an interesting characteristic of hashtags is their legibility or transparency. Lexical features, including those that lead to legibility (the number of words in a concatenated hashtag) have been identified as determinants of hashtag adoption and popularity (Ma et al., 2013). A simplified system of classifying the increasing lexical complexity of hashtags is to group them into three categories: (1) single word, (2) concatenations, and (3) opaque constructions. The final category includes a variety of hashtag constructions, including abbreviations, acronyms, and concatenations of these (see Figure 4.4).

Figure 4.4
Hashtag Characteristics and Legibility



Hashtag legibility does not provide a straight-forward indicator of whether or not a hashtag is intended to be used for search, or if it is performing another function. A common and legible word may be as useless as a search term as an obscure one, depending on the context. When used within the text of a tweet, a common word may not be intended as a means to draw an

audience through search, but rather as a highlighted concept for people already reading the tweet - a sign indicating a concept of value or importance. Obscure hashtags may encode a shared catchphrase or shibboleth, again highlighting shared values. While legibility does not provide an explicit guide to the intended use of a hashtag, it can be considered as one variable among others that aids in understanding the possible uses of a given hashtag.

Some hashtags are clearly classified according to the schema of Figure 4.4, with `#funny` clearly being a single word, `#mathisfun` clearly being a concatenation, and `#vnps` clearly being an acronym, some hashtags uncomfortably straddle these distinctions. The hashtag `#womeninstem` may seem more like a concatenation, particularly for those who are familiar with the acronym STEM (Science Technology Engineering and Mathematics) and read it as a word. Arguably, when occurring within a concatenation, an acronym may become less obscure as it is contextualized. The same is possibly truer for `#instantpd`, which also may arguably be placed in the *concatenation* category. The *opaque construction* category is a bit of an uncomfortable catch-all for quasi-words, acronyms, and concatenations of these with words and phrases. In a more fine-grained analysis of legibility, the *opaque construction* category could be subdivided into additional groupings of acronyms and acronym-word combinations. Additional analysis would be needed to determine where these subcategories fall on the legibility spectrum of Figure 4.4.

Table 4.9
Examples of Hashtag Legibility

legibility level	examples
single word	`#math`, `#assignment`, `#online`, `#algebra`, `#funny`
concatenation	`#mathchat`, `#iteachmath`, `#mathisfun`, `#thinkingclassroom`
opaque construction	`#mtbos`, `#womeninstem`, `#cgi`, `#vnps` , `#wodb` `#instantpd`

Profile Content

Profile content is obtained from Twitter API data through the `description` attribute (see Table 4.1). Profile data can be analyzed using the bag-of-words method, described above. Profiles can also be classified based on key words used, applying methods similar to Carpenter et al. (2019) to determine indicators of identity disclosure.

Engagement

Indicators of engagement are provided directly by attributes such as `follower_count`, `favorite_count`, and `retweet_count`. The public exposure of these indicators is both interesting and problematic; these indicators are not the result of special measurements taken by the observer-researcher: they are an instrumentation of the behaviour on the platform that is visible to the participants as well, and are an obvious (and integral) part of Twitter use. These exposed attributes pose the problem expressed through *Goodhart's law*: "When a measure becomes a metric, it ceases to be a good measure" (Manheim, 2016). Attributes that are potential indicators of engagement are sometimes the target of concerted efforts to inflate their value, so that the means of assessing engagement becomes an end in itself. Concerns about measurement distortion can, in part, be addressed by looking for multiple ways to assess discourse features, and by applying strategies that help to recognize spam profiles (profiles that often employ metric inflation strategies).

Table 4.10
Discourse Features and Indicators

feature	indicator
hashtags used	`hashtags` attribute
tweet content	`hashtags` attribute, frequent terms in `text` attribute
discursive style	addressivity (via hashtag placement), interrogation (via selected terms, use of question marks)
value expression	hashtag placement and legibility
profile content	key and frequent terms in `description` attribute
engagement	`favorite_count`, `retweet_count`, `followers_count` attributes, reputation index

Applying Models of Situated Learning

The second research question of this study concerns how theories of situated learning describe the phenomenon of Math Teacher Twitter:

> *RQ 2: How do theories of situated learning, such as the community of practice and affinity space models, help us understand the informal professional development practices of mathematics teachers on Twitter?*

To answer this question, the components of the affinity space and community of practice models described in Chapter 3 were used to interpret the Twitter discourse features of the phase-two dataset. These components and discourse features are listed in Table 4.11. There is no one-to-one

mapping between the components of the affinity space and community of practice models and the Twitter discourse features – each model component involves several discourse features, and each discourse feature contributes to the description of several components.

Table 4.11
Conceptual Framework Elements

concept / model	components / features
Twitter discourse	*hashtags used*, *tweet content*, *discursive style*, *values expressed*, *profile content*, *engagement*
Affinity spaces	*spaces of social learning*, *content and knowledge*, *portals and generators*, *specialist language varieties*, *shifting strategic identity*, *games and simulations*
Communities of practice	*identity and membership*, *reproduction*, *periphery and centre*, *transparency*, *discourse of practice*, *legitimacy*

In order to arrive at viable narratives that express how each model would interpret the observations of Math Teacher Twitter, the problem of integrating the components and features was approached from two directions. The analysis first proceeded from models of situated learning to Twitter discourse features, identifying which discourse features provide relevant data for each model component. For example, the affinity space concept of *portals and generators* is found to be associated with *hashtags used*, and the relative strengths of the portals and generators can be described by looking at *tweet content* and *engagement*. The second step in the analysis proceeded in the opposite direction and determined how each discourse feature may be interpreted in each model. For example, *engagement* may be interpreted in the affinity space model as an indicator of topicality and relevance, while the community of practice model would frame engagement as a measure of legitimacy.

Approaches to Applying Models of Situated Learning

In considering these models of situated learning, it is important to note that both models can be applied in different ways. The community of practice model can be applied critically or normatively, while the affinity space model can be applied presumptively or evaluatively.

Critical and Normative Applications of Communities of Practice. Much of the interest in communities of practice among educators is concerned with how positive and productive communities of practice can be nurtured or designed, either in schools or within professional development contexts. In this way, the community of practice concept can take on a *normative* or even

aspirational character (as for example in Wenger, 2011). However, the community of practice model, at least in its original formulation in Lave and Wenger (1991), is not normative, but rather *critical*, providing a perspective from which learning claims can be analyzed. As noted by Lave and Wenger (1991): "legitimate peripheral participation is not itself an educational form, much less a pedagogical strategy . . . it is an analytical viewpoint on learning – a way of understanding learning" (p. 40). A distinction must be drawn between describing a situation as a "community of practice" in the aspirational/normative sense and the critical sense. When applied normatively, "community of practice" describes a learning situation whose elements foster positive transitions from periphery to full participation, while critical applications of the concept may describe situations where community reproduction occurs but its mechanisms are not transparent and its learning claims are open to dispute. When considered critically, what is being learned in a community of practice is revealed through the investigation of the social relationships in that community and its process of reproduction. As Lave and Wenger (1991) note, this may not be the same as the declared purpose of the community or the topic that community members are ostensibly concerned with. The *learning curriculum* of the ambient community that is expressed through the changing social dynamic of community reproduction may be a form of *hidden curriculum* (as described by Portelli, 1993).

Presumptive and Evaluative Applications of Affinity Spaces. The affinity space model is based on observations of motivated engagement and learning that occurs in (primarily online) spaces that are "common today in our global high-tech new capitalist world" (Gee, 2004, p. 87). The new learning opportunities found in these spaces present a challenge to traditional schooling in how they offer an alternative model of what learning looks like, and also in that learners who encounter these spaces may find traditional learning to be stifling by comparison (Gee, 2004). The affinity space model represents an attempt to distill the essential elements of these spaces, place them in the context of an adapted set of situated learning principles, and to put these in the service of designing similar spaces in the service of equitable and accessible public education (Gee, 2017). Because the affinity space model takes its inspiration from online forums and similar websites, a *presumptive* approach is to assume that all such sites should be automatically regarded as affinity spaces. A more *evaluative* approach would be to take the identified elements of the affinity space model and verify their presence. Unlike the critical approach of community of practice, the affinity space model does assert that affinity spaces provide a better educational option: the only critique it offers is of "traditional schooling." Presenting an idealized notion of learning spaces, the affinity space model allows learning situations to be evaluated in terms of how effectively they offer strong generators, accessible portals, and motivated engagement with a topic of interest.

In developing interpretations of the phase-two dataset, I have attempted to present a critical application of the communities of practice model and an evaluative approach to using the affinity space model. To say that a community of practice is being observed does not necessarily imply that members are learning what they hope to learn, and an affinity space does not necessarily exist because participants are using an online platform. A critical application of the communities of practice model looks for components of the model, without necessarily associating them with assumed learning outcomes. For example, indications of *periphery and centre* indicate a gradient that a newcomer must pass through in order to become an old-timer: this may be an indication of learning how to talk about and model important concepts in teaching and learning, or it could represent the adoption of behaviours that are merely beneficial within the context of participating in Math Teacher Twitter. An evaluative approach to applying the affinity space model does not assume that although Twitter is a product of the "global high-tech new capitalist world" (Gee, 2004, p. 87) that Math Teacher Twitter will necessarily exhibit all components of affinity spaces. In particular, the contours of a *space of social learning* should not be assumed – the effectiveness of portals and generators to help define such a space in the context of spam and other non-topical exchanges should be evaluated. The bidirectional method described above supports this critical and evaluative approach by focusing on the model components and discourse features without introducing additional assumptions about the community/space being described.

Chapter 5

Analysis:

Describing Twitter Discourse

As described in Chapter 4, the first phase of the two-phase approach to addressing the research questions posed in this study uncovered four key Math Education Twitter Hashtags (METHs): `#mtbos`, `#iteachmath`, `#mathchat`, and `#math`. These key METHs were found to be used frequently across profiles in the phase-one dataset, and the set of tweets associated with these tags was found to be more topical (based on the frequency of most common terms) than other tweets in the dataset. These key METHS were queried to produce the phase-two dataset, a corpus of tweet data. Analysis of this phase-two dataset in terms of the features of Twitter discourse identified in Chapter 3 helps answer the question:

> *RQ 1: What are some of the important characteristics of the discourse associated with mathematics educators' informal professional development on Twitter?*

In this chapter, the Twitter discourse features identified in Chapter 3 will be described for the corpus of tweets making up the phase-two dataset. These features include the patterns of hashtag use, indicators of tweet content, the discursive style observed, indicators of expressed values, hashtag legibility, profile content, and engagement indicators (see Figure 3.2).

Hashtag Use

The hashtags identified as most frequently and widely used in Math Teacher Twitter, the key METHS, are surprisingly diverse in their surface characteristics. The `#mtbos` is an acronym for "Math Twitter Blogosphere," a reference to (a portion of) the online output of mathematics educators and practitioners, was first used as an acronym in 2013 (MathEd.net Wiki, 2015). The `#iteachmath` hashtag was proposed as a replacement to the `#mtbos` hashtag in 2017 by Dan

Meyer, who criticized it as being overly obscure, and consequently exclusive (Meyer, 2017). In contrast to these bespoke hashtags, tags with the `chat` suffix are a standard Twitter convention, in some cases referring to organized synchronous Twitter chats, but more generally denoting a post of relevance to the topic preceding the suffix shared asynchronously. With those brief observations in mind, we see that the four key METHs identified include:

1. A reference to a constructed or imagined entity or group, the "Math Twitter Blogosphere," known by the acronym `#mtbos`.

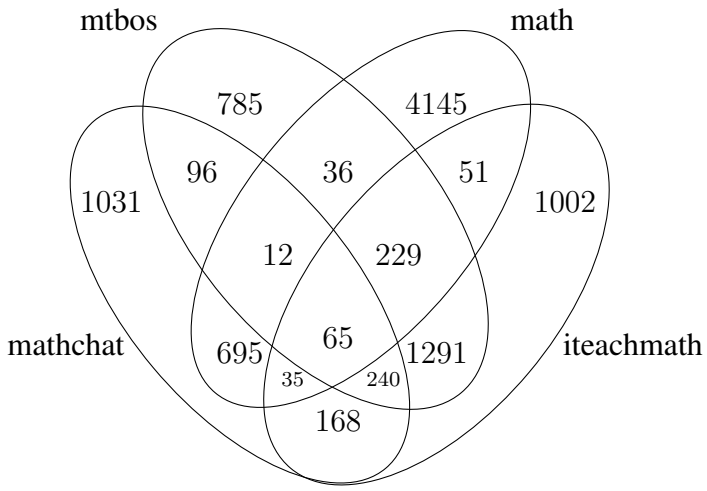
2. A declaration of personal status and identity, "I teach math," expressed through `#iteachmath`.

3. A signal of participation in an ongoing "math chat" conversation, indicated with `#mathchat`.

4. A statement about "math" being a subject of the tweet, shown by including the hashtag `#math`.

As shown in Figure 5.1, in the phase-two dataset all 15 ($2^4 - 1$) combinations of the four identified hashtags appear, although with varying frequencies. The sets defined by hashtag use show irregular overlap, suggesting relationships of partial inclusion and exclusion among them. These patterns may indicate both differences in awareness of what hashtags to use as well as deliberate choices to use particular hashtags or combinations.

Figure 5.1
Key METH hashtag combinations (n = 9881)



The Jaccard index (Equation 4.1) provides a probability-like measure of how frequently a pair of hashtags appear together. Table 5.1 shows the Jaccard index for each pair of hashtags based on the counts for retrieved tweets. This measure shows a strong level of co-occurrence for `#mtbos`

and #iteachmath ($j = .455$). The #math tag shows a weak level of co-occurrence with both #mtbos ($j = .076$) and #iteachmath ($j = .048$) tags. The #mathchat tag shows a weak to moderate level of co-occurrence with #math ($j = .119$), #iteachmath ($j = .103$), #mtbos ($j = .088$). The overlapping usage of these key METH is suggestive of relationships, and potentially of both shared and differentiated purposes.

Table 5.1
Jaccard Index for Key METH Pairs

	iteachmath	math	mathchat	mtbos
iteachmath	1	0.048	0.103	0.455
math	0.048	1	0.119	0.076
mathchat	0.103	0.119	1	0.088
mtbos	0.455	0.076	0.088	1

The #mtbos and #iteachmath hashtags show a high degree of co-occurrence, suggesting strong agreement as topical classifiers. Their co-occurrence is, at the same time, suggestive of differentiation in function between these two tags. The #mathchat hashtag, while occurring occasionally with #mtbos and #iteachmath occurs less frequently in conjunction with these, suggesting less topical agreement. #mtbos, #iteachmath and #mathchat tweets all occasionally use #math, but #mathchat is more likely to do so.

Table 5.2
Frequent Tags in Tweets by Key METH.[*]

key METH	tag 1	tag 2	tag 3	tag 4	tag 5
mtbos	iteachmath	mathchat	math	maths	edchat
$n_{tw} = 2754, n_{tg} = 7665$	0.2384	0.054	0.0453	0.0278	0.0168
iteachmath	mtbos	mathchat	math	maths	edchat
$n_{tw} = 3081, n_{tg} = 10099$	0.1807	0.0503	0.038	0.023	0.0173
mathchat	math	edchat	iteachmath	mtbos	edtech
$n_{tw} = 2342, n_{tg} = 11781$	0.0688	0.0457	0.0431	0.0351	0.0285
math	essay	assignment	homework	pay	online
$n_{tw} = 5268, n_{tg} = 51344$	0.0463	0.0372	0.0361	0.034	0.0299

n_{tw}: number of tweets, n_{tg}: number of tags.
[*]*Frequencies obtained from lists of hashtags associated with tweets.*

Table 5.2 shows the top five tags used in tweets that use a key METH (excluding the METH itself). The data in this table echoes those reported in Figure 5.1, in that it shows overlap among #mtbos, #iteachmath, and #mathchat, and that tweets with those tags also

frequently include #math. Along with the Jaccard index, Table 5.1, the hashtag frequencies confirm the strong mutual association of these tags, but unlike that calculation, Table 5.2 shows that the association between the other tags and #math is more unidirectional: tweets with #mtbos, #iteachmath, and #mathchat are likely to reference #math, but the opposite is not true. In the case of #mathchat, the more general #edchat pushes out the less conventional #mtbos and #iteachmath in terms of frequency.

The frequencies of hashtags associated with key METHs provides evidence that a distinction can be made between #mathchat and the #mtbos–#iteachmath pair. This data also shows that #math should be distinguished from these other METHs: while it is frequently used in tweets that employ the other three, the other hashtags are not frequently found in tweets that use #math. The hashtags used most frequently in conjunction with #math suggest that this hashtag is frequently applied to tweets that are likely to be considered as off-topic.

Beyond Key METHs

To move beyond the lists of key METHs that make up the most frequent tags associated with #mtbos, #iteachmath, and #mathchat, Table 5.3 shows the most frequent tags excluding key METHs. This shows that, when considering other hashtags, #mtbos, #iteachmath, and #mathchat involve topical "chat" tags (#edchat, #elemathchat), variations on the METHs that prefer the "maths" spelling of the United Kingdom (#maths, #mathschat), and with single-word hashtags that are on-topic (#mathematics, #education, #algebra). Distinctions between the compound hashtags favored by #mtbos and #iteachmath tweets and the topical single-word hashtags make up more of the #mathchat tweets will be explored in later sections of this chapter.

Other hashtags used in conjunction with the key METHs have the potential of pointing toward collections of tweets that use more specialized vocabularies. These groups of tweets may represent focused conversations about mathematics education that use more technical terminology. In order to get a sense of these potentially more focused interactions, two other hashtags were identified and their associated tweets (within the phase-two dataset) were collected: #apstats and #thinkingclassroom. The frequencies of other hashtags that appear along with the selected hashtags were calculated.

In the examples that follow, the hashtag distributions show the key METHs involved with the hashtag as the most frequent: this is expected as the data is drawn from the key METH corpus (each tweet has at least one of the four identified key METHs). The hashtag frequencies in these two sets conform to *Zipf's law* (see Equation 4.2), in that the frequency of each hashtag is inversely proportional to its rank. This observation illustrates the *vocabulary problem* identified in Chapter 4: there are many infrequently used and idiosyncratic hashtags, and those that are highly

Table 5.3
*Frequent Tags in Tweets by Key METH, Excluding Key METHs**

key METH	term 1	term 2	term 3	term 4	term 5
mtbos $n_{tw} = 2754$ $n_{tg} = 5077$	maths 0.042	edchat 0.0254	mathschat 0.0252	elemmathchat 0.0248	mathstalk 0.0238
iteachmath $n_{tw} = 3081$ $n_{tg} = 7382$	maths 0.0314	edchat 0.0237	elemmathchat 0.0195	mathematics 0.0177	mathstalk 0.0169
mathchat $n_{tw} = 2342$ $n_{tg} = 10049$	edchat 0.0535	edtech 0.0334	maths 0.0284	education 0.0255	algebra 0.0219
math $n_{tw} = 5268$ $n_{tg} = 49805$	essay 0.0477	assignment 0.0384	homework 0.0372	pay 0.0351	online 0.0308

n_{tw}: number of tweets, n_{tg}: number of tags.
**Frequencies obtained from lists of hashtags associated with tweets.*

ranked stand out significantly as having emerged from a socially-driven *folksonomic* processes.

In the example tweets that follow, the tweet classification frameworks of Larsen and Parrish (2019) and Staudt Willet (2019) were informally applied. Larsen and Parrish (2019) suggested a set of community building activities as classifications for MTBoS participants: *resource sharing*, *mentoring*, *dialoging*, *connecting*, and *encouraging*. Staudt Willet (2019) identified tweet purposes in terms of relational direction, classifying the tweets in terms of being pointed towards *self*, *others*, *mutual*, or *miscellaneous* (no classifiable direction). The example tweets listed in tables 5.5 and 5.7 are classified using both frameworks, using, for example *resource-sharing/self* sharing a resource created or provided by the tweet author.

The `#apstats` hashtag. The hashtag `#apstats` is ostensibly used to engage or share around the topic of "Advanced Placement Statistics" a course that is offered primarily in American high schools in conjunction with the College Board curriculum and exam. As shown in Table 5.4, `#apstats` is shared across both `#mtbos` and `#iteachmath` hashtags, sometimes occurring with both, and sometimes occurring with just one. An interesting hashtag of note here is `#effl`, which is an acronym for the slogan "Experience First, Formalize Later," expressing alignment with problem-based and constructivist-based approaches to learning.

Table 5.4
#apstats Associated Tags, 17 Tweets from 9 Profiles

Rank	Freq.	Tag list
1	13	#mtbos
2	9	#iteachmath
3	7	#apstatistics
4	6	#statschat
5	2	#distancelearning, #apdaily, #halloween2020, #effl
6	1	#mathchat, #statsmedic, #rhsroar, #aissharethelove, #redbrick125, #flamingo, #statsed, #statistics, #desmos, #geogebra, #teacherfunding, #lncpride

Table 5.5
#apstats Selected Tweets

	selected tweet	note
1	We just finished recording the last lesson for the AP Stats video library! 77 lessons complete! #apstats #MTBoS #apstatistics [**redacted url**]	resource-sharing/self
2	Has anyone done this project before (TPS ch 3)? I'm looking for examples of student work if you have any to share #apstats #statschat #apstatistics #MTBoS #iTeachMath [**redacted url**]	dialoging/mutual
3	#APstats Ss #EFFL 'd conditional prob and tree diagrams through some poker simulation. Now onto some trickier examples . #LNCpride @TheStatsMedic #iteachmath @LNCharter #mtbos [**redacted url**]	resource-sharing/self

The #thinkingclassroom hashtag. The #thinkingclassroom is a reference to the *thinking classroom* pedagogic principles championed by Liljedahl (see for example Liljedahl, 2020). This hashtag is found to almost always be accompanied by #mtbos. An interesting hashtag that may be puzzling to those unfamiliar with thinking classroom principles is #vnps, which those in the know will parse as *vertical non-permanent surface*, a tool that is frequently integrated with thinking classroom practice.

Table 5.6
#thinkingclassroom Associated Tags, 28 Tweets from 21 Profiles

Rank	Freq.	Tag list
1	20	#mtbos
2	17	#iteachmath
3	6	#mathchat
4	4	#vnps
5	1	#sidewalkmath, #mathwalk, #sandiegomath, #math, #calculus, #edchat, #distancelearning, #yrdsb, #abed, #cdned, #mmr, #mmronline2020, #mmrobinsonhs, #hybridlearning, #peelfam, #lrsd68, #canyonschoolrocks, #cohort21, #mcv4u, #ksedchat, #teachertwitter, #mathedchat, #ocv, #learningathome, #vrg, #ibapplications, #sisrocks

Table 5.7
#thinkingclassroom selected tweets

	selected tweet	note
1	Hey #MTBoS how have you reimagined assessment (and in particular exams) in the age of hybrid learning? Tools? Strategies? Looking for ideas! #iteachmath #mathchat #ThinkingClassroom #cohort21 #mcv4u	dialoging/mutual
2	New blog post up: #ThinkingClassroom Book Club #MTBoS #MathChat [**redacted url**] #EdChat	resource-sharing/self
3	I was wondering if there was a conversation somewhere about #VNPS and #thinkingclassroom in the context of online learning. What have people tried? What worked and what didn't? [**redacted mention**] #mtbos	dialoging/mutual

The #tmwyk hashtag. The #tmwyk hashtag is an acronym for "Talking Math with your Kids," and is generally used as a way for mathematics educators to share personal experiences of talking

about mathematics with their own children. It is also an example of branding/micro-celebrity, as the hashtag is associated with a well known math educator's professional development and resource provider website (Danielson, 2022).

Table 5.8
#tmwyk Associated Tags, 21 Tweets from 16 Profiles

Rank	Freq.	Tag list
1	20	#mtbos
2	9	#iteachmath
3	1	#playfulmath, #math, #openupmath, #art, #annmath, #womeninstem, #amityfamily, #elemmathchat, #lookforcirclesday, #mathart, #kidsofmtbos, #music, #homeschoolmath, #mathkids, #estimation

Table 5.9
#tmwyk selected tweets

	selected tweet	note
1	So many great conversations came out of this [**redacted mention**] activity with my fourth grader. Building her confidence is the first step in giving her tools to one day take over the world. #tmwyk #mtbos #iteachmath #womeninSTEM	connecting/other
2	Friday night is for the kiddos homework! Its all about prime factorization and lowest common. There was a lot of discussion around what a prime number and multiple mean. Why do some lcm end up being the numbers multiplied and others end up being less that that? #tmwyk #mtbos	dialoging/mutual
3	It all started with, ``How many do you think there is in these two containers, Mummy?'' Now she's making use of counting by 2, 5, and 10 to see whose estimating is better. How would you count the beads? #iteachmath #mathkids #estimation #tmwyk	dialoging/mutual

Other hashtags are used in conjunction with key METHs potentially identifying more narrow topics within the broader context of Math Teacher Twitter. These hashtags are not strictly associated with a particular key METH but may occur in tweets that include various combinations of key METHs (and possibly in tweets that contain no key METHs). These other hashtags may be obscure or ambiguous to those who do not understand the technical language associated with the topic.

Tweet Content

To understand (at least approximately) the topics associated with the key METHs in the phase-two dataset, the content of the tweets associated with the particular hashtags needs to be assessed. Two methods for doing this are to look at (1) the other hashtags found in tweets associated with each key METH and (2) looking at frequent terms in these tweets.

Among the understood uses of hashtags is that they highlight important terms and identify topics, both of which provide information about tweet content. Consequently, an approach to understanding the content of the tweets associated with each key METH is to look at the *other* hashtags that appear as part of the content of the tweets associated with each METH. This approach is methodologically straightforward, as the hashtags associated with each tweet are provided directly in the `hashtag` attribute, so processing of tweet content is not required to extract this data.

Frequencies for the most common hashtags associated with each key METH are reported in the previous section in Table 5.2. Except for the hashtags associated with `#math`, these most frequent hashtags reported in Table 5.2 do not reveal many clues about tweet content the most frequent tag lists are simply restating the key METHs lists, and not others that may provide clues to content. Table 5.3, which lists the frequent hashtags other than key METHs, shows that tweets associated with METHs other than `#math` frequently contain other topical hashtags. The most frequent hashtags used in `#math` tweets are different than those associated with the other key METHs, showing that as a group `#math` tweets are less frequently associated with the topics that other key METHs identify, and are instead likely associated with commercial concerns. If we were to infer anything about the most frequent content of `#math` tweets from 5.2, it would be that it was used by services offering to buy or pay for essays, assignments, and homework.

Turning to tweet content beyond hashtags, the term frequencies of Table 5.10 indicates a broad agreement in content among the tweets that use `#mtbos`, `#iteachmath`, and `#mathchat`, as well as qualitative agreement with the assumed topic of *mathematics education* relevant to the professional development of mathematics teachers. This agreement provides a level of confirmation that the hashtags `#mtbos`, `#iteachmath`, and `#mathchat` do indeed grant access to content related to mathematics education when used as search terms.

The term frequencies of Table 5.10 also provides further confirmation that, when treated as a search term, the hashtag `#math` returns tweets that are off-topic and that many of the posts under the `#math` may be offering or requesting assignment writing services. Based on the terms observed here, many tweets returned by searching for `#math` might be labelled as "spam tweets."

Analysis of term frequencies associated with key METHs shows that, as assessed by most

Table 5.10
*Frequent Terms in Tweets by Key METH**

key METH	term 1	term 2	term 3	term 4	term 5
mtbos	student	teach	learn	desmos	problem
$n_{tw} = 2754, n_{tm} = 41745$	0.0128	0.0125	0.0076	0.0059	0.0047
iteachmath	teach	student	learn	today	desmos
$n_{tw} = 3081, n_{tm} = 46712$	0.0124	0.0121	0.0091	0.0055	0.0046
mathchat	teach	learn	student	education	edtech
$n_{tw} = 2342, n_{tm} = 35627$	0.0166	0.0139	0.0123	0.0104	0.0095
math	pay	essay	assign	paper	due
$n_{tw} = 5268, n_{tm} = 104421$	0.0346	0.0313	0.0282	0.0267	0.0247

n_{tw} denotes the number of tweets, n_{tm} denotes the number of tags.
Terms which are also exclusively or predominantly hashtag names have been removed.
**Frequencies of terms based on bag-of-words method applied to tweet content.*

frequent terms, the sets of tweets associated with `#mtbos`, `#iteachmath`, and `#mathchat` are broadly on-topic. This analysis provides evidence that, taken as a group, tweets associated with `#math` display characteristics of *spam* and may be largely off-topic.

Discursive Style

As described in Chapter 4, distinctions between participatory and broadcast talk can in part be indicated by the engagement strategies that these discursive styles employ. One engagement strategy of participatory talk is *addressivity*, and a particular form of this strategy is illustrated when hashtags (rather than specific mentions) are used to address a group. Although there are various ways that this group addressing can be expressed, hashtag placement at the front of a tweet can be an indicator that the hashtag is being used to address an imagined audience. Another engagement strategy of participatory talk is *interrogation*, which can be indicated by the use of question words or question marks.

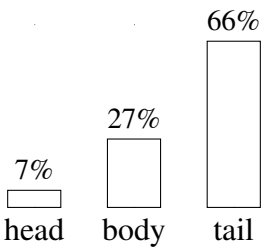
Hashtag Placement and Addressivity

Looking at the positions of key METH hashtags across the phase-two dataset, some distinctions can be observed among them, as shown in Figure 5.2. The most frequent positions for `#mtbos`, `#iteachmath`, and `#mathchat` are in the tail, indicating that often these are used as classifying hashtags (Figures 5.4a, 5.4b, 5.4d). The `#mtbos` hashtag is more than twice as likely to appear at the head of a tweet than `#iteachmath` or `#mathchat`, suggesting that of

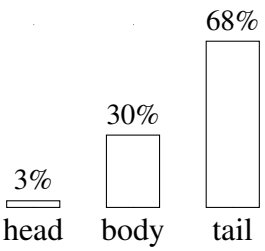
those three, #mtbos is more often used as an address.

Most strikingly, the position distribution for #math (Figure 5.4c) is uniform - it is as likely to appear in any position as another within the body of a tweet. Spam tweets that present a stream of hashtags, such as the examples in Table 5.12, contribute to the flat distribution seen with the #math hashtag. As noted by Carpenter et al. (2020), patterns of hashtag use illustrated by the examples of Table 5.12 and by indiscriminate hashtag use shown in the uniform distribution of #math in 5.2 are indicators of spam behaviour.

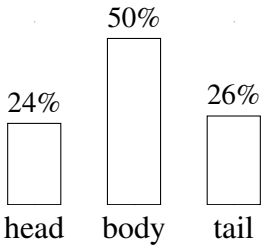
Figure 5.2
Position frequencies for key METHs



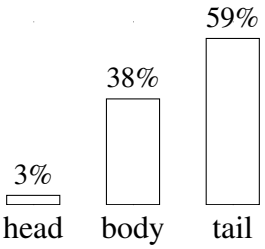
(a) *#mtbos position,* $n_t = 2751$



(b) *#iteachmath position,* $n_t = 3082$



(c) *#math position,* $n_t = 5330$



(d) *#mathchat position,* $n_t = 2349$

n_t: number of tweets.

Hashtag placement data reaffirms the observations from tweet content that the topic hashtag #math frequently occurs in spam tweets, and is used along with other topical hashtags in attempts to broadcast these out.

As noted by Figure 5.2, the #mtbos is seen in the head/addressing position more frequently than #iteachmath and #mathchat, suggesting, as implied by its name, that it is more likely to be perceived as naming an entity or group. Not all addresses to this imagined group use the construction of placing the hashtag at the head, however, as shown in the examples of Table 5.13. That the #mtbos is framed syntactically as an entity (a "blogosphere") and is used (although far from predominantly) in explicit addressing, suggests that the hashtag is conceptualized among some of its users as naming an entity or group.

Table 5.11
Placement and Function of Hashtags in Selected Tweets

Selected tweets	Hashtags	Placement and function
How about a number hunt in the halls on a rainy day? | The children decided how they were going to organize the data they found on our walk. When finished we analyzed our results. What number was | found the most? Least? Encouraging **#math** talk about our findings. **#joyfulmath #MTBoS** [**redacted url**]	#math, #joyfulmath, #MTBoS	Placement at tail, suggesting classifying function.
A student version of a | **#rubric** helps even the youngest mathematicians understand what's expected and | supports self **#assessment #ITeachMath** [**redacted url**]	#rubric, #assessment, #ITeachMath	Placement in body and tail, suggesting classifying and highlighting functions.
Hey **#MTBoS**: If you *had* to choose | one, would you use 'Savas enVisionmath', or 'Great MindsEureka Math in Sync'? Is anyone already | using one of them? **#alg2chat #geomchat**	#MTBoS, #geomchat, #alg2chat	Placement at head and tail, suggesting addressing and classifying functions.

Head, body and tail boundaries are designated by pipe markers (|).

Hashtag placement shows that, more than #iteachmath and #mathchat, the #mtbos hashtag is used addressively, as if to be framing the tweet as a direct appeal to the group *MTBoS*. Examples of indirect addressing can also be found, where the context of the tweet suggests that it is being directed towards the MTBoS entity, confirming that placement is only a partial indicator of the more general phenomenon of addressive use of #mtbos. Hashtag placement also shows that the #math, is found uniformly throughout the body of tweets, suggesting indiscriminate placement consistent with *spam* tweets.

Interrogation and Participatory Talk

Two measures of the *interrogation involvement strategy* the involvement strategy of asking questions applied to the phase-two dataset were (1) the frequency of interrogative words

Table 5.12
Example Spam Tweets Using #math Hashtag

Selected tweets	hashtag location
Kindly DM for: #businesslaw **#Math** | #Algebra #Calculus #Statistics #biology #Nursing #Essay #Assignment #Assist #research #dissertation #Project #marketing #physics #chemistry | #geometry#homework #paysomeonewrite #essayhelp #AssignmentHelp #Essaydue	#math in head
Do you need academic help? We guarantee you excellent grades | if you allow us to help you out with #homework #assignment #discussion #online class #research paper #pay someone write | #Payessay due #pay history. #psychology **#math** #assignment DM for a good deal	#math in tail
Hit Me Up for professional assistance in: | #Onlineclass #Statistics #Termpapers #Assignments #Physics #economics #Accounting #History #Finance **#Math** #LAW #Biology #Dissertation | #Research #Psychology #Thesis #English #Chemistry #Literature #Essay [**redacted email address**]	#math in body

Head, body and tail boundaries are designated by pipe markers (\|).

(what, when, why, how, who, and where), and (2) the presence of question marks. Table 5.14 shows the frequencies for these formal marks of interrogation for tweets containing each key METH. Both indicators of the use of the interrogative involvement strategy (use of interrogative words, use of question marks) show consistently that #mtbos tweets use this strategy the most frequently. By these indicators #math tweets use interrogation less than half as often as #mtbos tweets.

It can be hypothesized that the ability to conceive #mtbos as an entity leads both to its more frequent addressive use, and to the higher frequency of interrogative tweets that use this hashtag. While #iteachmath was proposed as an alternative to #mtbos, it may be that this special quality of the #mtbos tag – that it aids the conceptualization of an imaginary group – helps to explain its longevity as an independent hashtag as well as its frequent co-occurrence alongside #iteachmath. Furthermore, this conceptualization is an important enabler of involvement strategies that facilitate participatory talk.

Table 5.13
Example Tweets Addressing #mtbos

Selected tweets	implicit/explicit
Ninth grade science students got stuck converting 1000s to minutes. What are your gems for teaching conversions? #iteachphysics **#MTBoS** #modphys #iteachchem [**redacted url**]	An implicit address with tags in tail.
Help: Id love to see your responses to this prompt with a social justice theme: How it started...How's it's going?, along with a relevant graph Please reply to this post with your response to the prompt! If I get enough, I'll combine and share! **#MTBoS** #SJMath	An implicit address with tags in tail.
#MTBoS does anyone else detail their slides to death? One class, 2 hours later...not sustain-able...and yeah, fun. [**redacted url**]	Explicit address in head position.
#MTBoS the history teacher at my school wants to discuss the Electoral College with our 8th graders, and wants a math perspective of how it's possible to lose the popular vote but win the electoral vote. Send me your best resources/explanations!"	Explicit address in head position.
Hi **#MTBoS** peeps! Who's going virtual at the @CMC conference tmrw with me? I'm so excited!! Let's @Desmos @openmiddle @noticeandwonder together!"	Explicit address in head position.

Table 5.14
Frequency of Interrogative Strategy Use by key METH

hashtag	n_t	interrogatives	question marks
mtbos	2754	35.004%	29.63%
iteachmath	3081	30.185%	22.136%
mathchat	2342	27.37%	18.83%
math	5268	12.472%	10.118%

n_t denotes the number of tweets.

High Frequency Hashtag Use

A marker of broadcast talk on Twitter is high-frequency hashtag use (Page, 2012). High-frequency hashtag use has also been noted as a potential indicator of spam content (Carpenter et al., 2020), and it makes sense this metric would apply in both cases, with spam being a particular example of *broadcast talk*. As shown in Table 5.15, `#math` stands out in terms of frequent use of hashtags, and examples of spam tweets using `#math` in Table 5.12 illustrate why this ration is as high as it is.

The frequency of hashtag use suggests that `#mtbos` may have a lower level of broadcast talk associated with it than `#iteachmath` or `#mathchat`. Searching using the `#math` hashtag returns content that is more likely to be of the broadcast variety, and, as confirmed by other indicators, is more likely to be considered spam.

Table 5.15
Tweet to Hashtag Ratio by Key METH

key METH	tweet count	hashtag count	hashtag/tweet ratio
mtbos	2754	7665	2.82
iteachmath	3081	10099	3.28
mathchat	2342	11781	5.03
math	5268	51344	9.75

Value Expression

As noted in Chapter 2, linguistic studies of Twitter discourse have noted that hashtags can play a role in creating a sense of affiliation by expressing shared values (Zappavigna & Martin, 2018). Situations in which hashtags fail to perform a search function stand out as possible examples of this form of value expression. Hashtag legibility provides an indicator of how well a hashtag might be recognized without specific insider knowledge and has been found to be related to levels of hashtag popularity (Ma et al., 2013), so may provide some clues to how *searchable* a hashtag is. Interestingly, equating legibility with searchability is not straightforward, as hashtags can fail at being useful search terms both when they are too easily understood (and hence overused) and when they are difficult to recognize. While overly popular or ambiguous words will always be of limited use in search, an obscure hashtag that becomes popular among a significant group of users can become a useful search term, if you are among those who know about it.

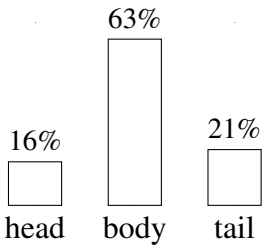
Rather than being used for search purposes, playful and obscure hashtags such as `#mathtrainsbrains` may highlight a feeling or belief, rather than indicate an intention to link to other Twitter content. An example of a less flamboyant but rather ambiguous hashtag

is #cgi, which in the context of math education discussion generally stands for "cognitively guided instruction," but when searched for generally will return primarily content concerned with "computer generated images." Seemingly non-ambiguous hashtags that are more common words, such as #math, can fail as search terms that grant access to specialized content because of their widespread use. Using hashtags such as #math within the text of a tweet, rather than only as topical markers at the end of a tweet, may represent a more knowing/deliberate use that seeks to draw attention to key ideas and express values that can be appraised by others. Table 5.16 includes examples of tweets that use #math in a highlighting capacity, rather than a strictly classifying capacity. While these hashtags fail as search terms (anyone searching for them would see non-relevant spam results), they can still function within tweets as markers of shared values. A wide range of hashtags including ones that are obscure (#mtbos), ambiguous (#cgi), and common (#math) may be used for linguistic and paralinguistic (performative) purposes other than the classifying and search-related functions that hashtags are often assumed to be fulfilling.

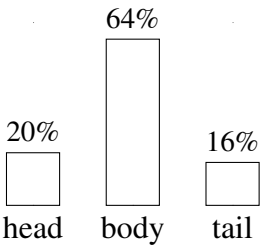
Tweets, where the general #math hashtag is used in conjunction with another key METH (#mtbos, #iteachmath, or #mathchat), are more likely to illustrate the use of #math as in a highlighting function, rather than as a searchable term. Table 5.16 provides example tweets from the key METH corpus where #math is used in non-spam tweets as a way of emphasizing and expressing value. Figure 5.3 considers cases where #math is used in conjunction with #iteachmath or #mtbos and with #mathchat. Here the #math is used in positions more closely resembling the "expected" non-Spam distribution, and a less uniform distribution is observed.

Figure 5.3

Position Distribution for #math in Combination with #mtbos and #iteachmath



(a) *In combination with #mtbos and #iteachmath ($n_t = 433$).*



(b) *In combination with #mathchat ($n_t = 811$).*

n_t: number of tweets.

The idea that hashtags can be used not for search, but rather to signal something of value or importance to someone already reading the tweet, helps to explain why #math appears frequently in tweets with other key METHs, while on its own seems to be associated with spam. Differentiating between these two uses, the position of #math when it appears along with an-

Table 5.16
Example Non-Spam Tweets that Include #math

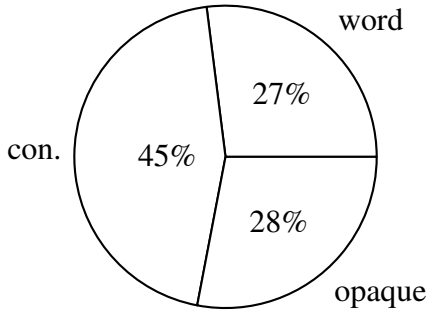
Selected tweets	hashtag location
As I work on inquiry collections, I've been reconnecting with my understanding of #music. It is a beautiful intersection of #art & **#math** So many avenues for discussion and connection. Great convo about fractions, symbology and the staff w the kids today. **#mtbos** #tmwyk #mathart	#math in body, #mtbos in tail
Using a great twitter thread from [**redacted twitter handle**] for a fun geometry project with my younger son: [**redacted url**] **#math #mathchat**	#math and #mathchat in tail
#MTBos, get you some data for your class! [**redacted url**] I am ready to write a new@NCTM proposal called ''What Had Happened Was ...'' based on these data trends over the last few days. This was always a **#math** problem. #CountEveryVote	#mtbos in head and #math in tail (used as highlighting).

other METHs is less indiscriminate, and skews more towards being used in the body of a tweet, where it may be performing a a highlighting function.

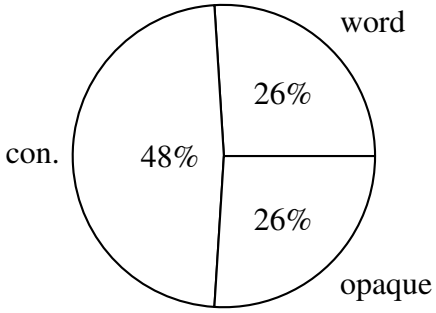
As noted in Chapter 4, a simplified system of classifying the increasing lexical complexity of hashtags is to group them into three categories: (1) single words, (2) concatenations, and (3) opaque constructions. According to this system, #math falls into group (1) as a single word, #mathchat and #iteachmath fall into group (2) as a concatenation of words, and #mtbos falls into group (3) as an acronym. In addition to looking at the legibility of each key METH, the legibility of the other hashtags that co-occur with each key METH can be assessed to measure the general legibility of hashtags that occur in conjunction with them. For each key METH, the 150 most frequent other co-occurring hashtags (excluding other key METHs) were evaluated and categorized according to the scheme of Figure 4.4. Weighted according to their frequency, the hashtag distribution among these categories for each key METH is shown in Figure 5.4.

Hashtags used along with #mtbos, #mathchat, and #iteachmath show a similar level of opaque constructions (with 28%, 26% and 25% of the more frequent hashtags from those groups being opaque constructions, respectively), while hashtags co-occurring with #math are far less likely to be opaque constructions (with only 2% of these hashtags being classified as an opaque). While #mtbos and #iteachmath show similar distributions across all hashtag legibility levels, #mathchat tweets show a greater use of single-word hashtags, with 42% of of most frequent co-occurring hashtags being a single word, compared with 27% and 26% for #mtbos and #mathchat. The tendency of tweets associated with #mathchat to favour more

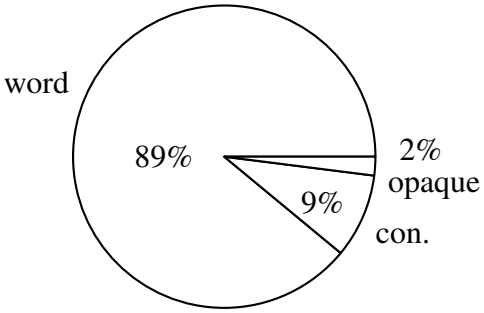
Figure 5.4
Legibility of Hashtags Co-occurring with Key METHs, as Classified by 1. single words (word), 2. concatenations (con.), and 3. opaque constructions (opaque)



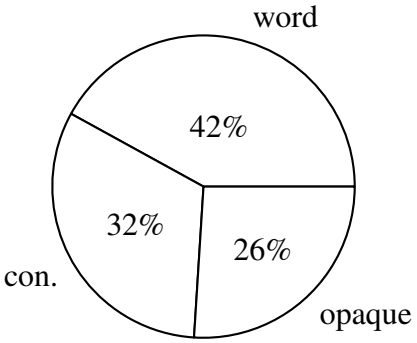
(a) `#mtbos`, $n_t = 3601$



(b) `#iteachmath`, $n_t = 4572$



(c) `#math`, $n_t = 48288$



(d) `#mathchat`,$n_t = 13101$

n_t: number of hashtags

legible single-word hashtags is also noted in Table 5.3.

Hashtag legibility provides another measure that confirms that #math tweets, as a group, have different characteristics than those of the other key METHs. In this case, the legibility of hashtags associated with #math suggests that they provide less affiliation and value-sharing than other key METHS. The #mtbos and #iteachmath tweets have more *concatenations* than #math, which has more single word hashtags, suggesting that the #mtbos – #iteachmath pair may coincide with more frequent expressions of value and affiliation.

Profile Content

The Twitter profile provides users with an opportunity for self-identification. As noted by Carpenter et al. (2019), educators navigate the platform's demands for self-disclosure along with privacy concerns when deciding which aspects of their personal and professional identities to put forward in their Twitter profiles. While the Twitter hashtag provides a means of expressing the relevance of a particular tweet to a topic or audience, the profile provides a mechanism for providing a more persistent statement of personal identity or interest in a particular topic. We can consider the extent to which the profiles of hashtag users align themselves with the topic designated by the hashtag. The answer to this question provides an indication of the extent to which a particular hashtag provides a space where enthusiasts share their interests.

The key METH corpus includes a set of 3133 user profiles. The description of each profile was parsed for *mathematics* related and, *education* related terms. The frequency of profiles that included these identified terms is reported in Table 5.17 by each key METH.

Table 5.17
Profile Topic Identification by key METH

key METH	n_p	math profiles	ed profiles
mtbos	821	76.492%	82.948%
iteachmath	878	72.893%	84.169%
mathchat	575	32.522%	78.435%
math	1774	19.56%	38.952%

n_p denotes the number of profiles.

Instead of looking for identification with a presumed topic such as *math* or *education*, we may ask more generally what terms the users of particular hashtags use to describe themselves. Table 5.18 shows a striking similarity among the top five most frequent terms used in profiles in that tweeted with the various key METH combinations. Excepting tweets using the #math hashtag exclusively, the three most frequent terms in profiles that use all combinations of METHs

are *math*, *education*, and *teacher*. It is important to note that the text mining methods that tabulate term frequency truncate words to common roots, so *math* represents a class of words that include "math," "mathematics," "mathematical," etc. Tweets containing the `#math` hashtag without other key METH tags stands out from the other combinations, in that it features terms such as *essay*, *online*, *assign*, and *help*. It turns out that the prevalence of these terms indicates that a significant number of profiles tweeting with the `#math` tag are profiles that are offering essay and assignment writing services.

Although `#mathchat` profiles shares the same top five most frequent terms as those associated with `#mtbos` and `#iteachmath`, the actual frequencies differ in interesting ways, with *math* and *teacher* having significantly lower frequencies for `#mathchat`. The self-descriptions of `#mathchat` users encompass a wider range of terms, lowering the frequencies of the top terms identified, indicating more overall diversity in the profile descriptions that those users present.

Profiles that contain words related to the terms math and education are more likely to be found associated with `#mtbos` and `#iteachmath` than among those using `#mathchat`. Among the users of `#mtbos` and `#iteachmath` we are more likely to find profiles explicitly declaring an interest in math and education. The hashtag `#math` is least likely to be associated with profiles containing these terms, again setting that hashtag apart, and suggesting that some of the content associated with this hashtag may be off-topic. The most frequently used hashtags among profiles containing both math and education terms are less legible than hashtags observed generally across the phase-two dataset, suggesting that the tweets associated with these profiles may include more frequent expressions of values and affiliation.

Table 5.18
Frequent Profile Terms by Key METH

key METH	term 1	term 2	term 3	term 4	term 5
mtbos	math	teacher	education	learn	school
$n_p = 821, n_t = 9116$	0.08	0.0457	0.0207	0.0163	0.0163
iteachmath	math	teacher	education	learn	school
$n_p = 878, n_t = 9394$	0.0775	0.045	0.0219	0.0183	0.0155
mathchat	math	teacher	education	learn	student
$n_p = 575, n_t = 6648$	0.0332	0.028	0.0269	0.022	0.0102
math	math	essay	education	online	teacher
$n_p = 1774, n_t = 18008$	0.02	0.014	0.0116	0.0094	0.0093

n_p denotes the number of profiles, n_t denotes the number of terms.

Patterns of Engagement

In some cases, the choice of applying a particular hashtag combination is an attempt to label the content of the post so that it will be found by a particular audience (Zappavigna, 2015). In these cases, the use of hashtags can be seen as a means of promoting engagement. Two readily available methods of measuring engagement with a particular tweet are how many times the tweet receives a *favourite* or *like* from a user, and how many times the tweet gets *retweeted*. Table 5.19 summarizes the mean and standard deviation of the favourite counts of tweets for each hashtag combination (m_f and sd_f) and the mean and standard deviation of the retweet counts for each (m_r and sd_r). Tweets with `#mtbos` and `#iteachmath` have the highest mean measures of engagement, while `#math` without other tags has the lowest mean engagement measures. As reported by Table 5.19, there is wide variation in these measures, reflecting the fact that while most content online may go unread, some content experiences *viral* sharing that is closely reflected in engagement metrics (Alhabash & McAlister, 2015). Beyond engagement with specific hashtags, Table 5.20 suggests that tweets that have at least one opaque hashtag generally receive greater interaction than tweets that only use single-word or compound word hashtags.

Table 5.19
Tweet Engagement by Key METH

key METH	n_t	m_f	sd_f	m_r	sd_r
mtbos	2754	8.021	31.323	2.489	5.967
iteachmath	3081	6.851	29.047	2.38	5.587
mathchat	2342	4.326	18.148	1.58	3.813
math	5268	1.977	14.54	0.745	3.219

n_t: number of tweets, m_f: mean favorite count,
sd_f: standard deviation of favorite count,
m_r: mean retweet count, sd_r: standard deviation of retweet count.

Table 5.20
Engagement by Hashtag Legibility

hashtag legibility	n_t	m_f	sd_f	m_r	sd_r
opaque	3964	6.556	28.081	2.127	5.314
non-opaque	1772	4.628	14.215	1.639	3.406

n_t: number of tweets, m_f: mean favorite count,
sd_f: standard deviation of favorite count,
m_r: mean retweet count, sd_r: standard deviation of retweet count.

Engagement can be expressed at the profile level as well as at the tweet level. Participants (generally positively) engage with other profiles by following them, which adds the content produced by that profile to their Twitter timeline. As noted in Chapter 3, a derived measure of engagement with a profile is its reputation index (see Equation 3.1). Table 5.21 provides summary statistics for the reputation index of profiles using each key METH. The mean reputation index is highest for profiles that use `#iteachmath` (0.421) and `#mtbos` (0.421), and lower for those that use `#mathchat` (0.156). Profiles that use `#math` have a mean reputation index of 0.206, above that of `#mathchat` users, but below `#iteachmath` and `#mtbos` users.

Table 5.21
Reputation by key METH

key METH	n_p	m_r	sd_r
mtbos	821	0.421	0.243
iteachmath	878	0.46	0.247
mathchat	575	0.156	0.206
math	1774	0.206	0.251

n_p: number of profiles, m_r: mean reputation index, sd_r: standard deviation of reputation index.

On average, there is greater engagement with tweets that use the `#mtbos` and `#iteachmath` hashtags than with the `#mathchat` hashtag, while the `#math` hashtag shows the lowest level of engagement among all identified key METHs. The higher reputation scores associated with the `#mtbos` and `#iteachmath` tags suggests that users of those hashtags are more involved Twitter users, that have accumulated a higher ratio of followers than the profiles that use `#mathchat` and `#math`.

Summary: Describing Math Teacher Twitter Discourse

The identification of key METHs in phase-one of this study and the analysis of the phase-two dataset obtained from queries using these key METHs show that these hashtags play a role in providing access to and structuring Math Teacher Twitter. Content analysis shows that `#mtbos`, `#iteachmath` and `#mathchat` are associated with Twitter content that frequently contains terms linked to mathematics education (Table 5.10). Hashtag co-occurrence (Figure 5.1 and Table 5.1) suggests that `#mtbos` and `#iteachmath` are more closely associated with each other than with `#mathchat`. Several metrics, including associated hashtag use (Table 5.2), term frequency (Table 5.10), hashtag legibility (Figure 5.4, and engagement (Table 5.19), along with indicators of broadcast discursive style (such as hashtag/tweet ratio in Table 5.15) reinforce the

finding that, taken as a group, tweets associated with #math are less topical and may frequently be categorized as spam.

Looking at the discursive style used across these identified hashtags demonstrates that the #mtbos hashtag facilitates participatory talk, which expresses itself in addressing (Figure 5.2) and interrogating (Table 5.14). Following the categories of tweet purposes established by Staudt Willet (2019), #mtbos, by helping to conceptualize, name and address a group, facilitates tweets whose purpose would be classified as *others* or *mutual*. In distinction, the #iteachmath hashtag explicitly provides a reference to *self* which fails to provide the opportunity to address and interrogate in the same way that #mtbos does, but perhaps provides a more explicit way of self-identifying as someone who can legitimately participate in Math Teacher Twitter. This distinction provides an explanation for the frequent co-occurrence of #mtbos and #iteachmath: while both hashtags point to essentially the same or similar content, they serve different purposes in constructing the group and individual identities at play.

Measures of value expression, profile content, and engagement suggest that #mtbos and #iteachmath users can be generally distinguished from #mathchat users in terms of their use of less legible hashtags (Figure 5.4), their stronger identification with math-related terms in their profiles (Table 5.17), along with greater engagement (Table 5.19 and 5.21). These distinctions may be indicators that #mtbos and #iteachmath are used more by educators who specialize in mathematics, rather than educators who happen to teach some mathematics, or that users of #mathchat include those who are merely using the *chat* convention and are not aware of the more specialized tags. Aside from what it may suggest about involvement in mathematics education, metrics such as the reputation index indicate that users of #mtbos and #iteachmath may be more effective at engaging on Twitter, perhaps reflecting a better use of Twitter conventions, or more frequent and longer use of the platform.

The #math hashtag provides an interesting example of a hashtag that is widely used by participants in Math Teacher Twitter interactions (as evidenced by its co-occurrence with other key METHs), but that cannot be used as an effective search term because it is overwhelmingly *common* and frequently used in spam and other off-topic tweets. The knowing use of this hashtag by participants in Math Teacher Twitter includes its employment as a value term, used to highlight the importance of the word *math* as a means of building affiliation with others who share a sense of its importance.

As revealed through Twitter discourse features, Math Teacher Twitter encompasses a variety of participants and content. It includes participants who present themselves as focused on mathematics and education (through their profile declarations), and who knowingly use multiple hashtags that serve distinct purposes in how they present both the participant and the content they are sharing. Math Teacher Twitter also includes more casual participants, who may be less

specialized in mathematics education, less aware of conventions that have developed within Math Teacher Twitter, or are less invested in developing relationships or presenting an identity. Participants in Math Teacher Twitter interact using discursive styles that are both participatory and broadcast-like. Participants in Math Teacher Twitter produce and engage with content on topics of mutual interest that also express shared values, and interact against a background of less topical and spam content that they selectively avoid and distinguish their contributions from.

Chapter 6

Analysis:

Applying Models of Situated Learning

In this chapter, the *affinity space* and *community of practice* models of situated learning outlined in Chapter 3 are compared with the observations of Math Teacher Twitter obtained by analyzing the features of Twitter discourse in the phase-two dataset. Interpreting the features of Twitter discourse described in the previous chapter (Chapter 5) using the components of each model provides narrative descriptions of Math Teacher Twitter that, while reflecting the theoretical perspective of each model, remain grounded in observations made at the Twitter discourse level. These narrative descriptions provide a response to the second research question asked by this study:

> *RQ 2: How do theories of situated learning, such as the community of practice and affinity space models, help us understand the informal professional development practices of mathematics teachers on Twitter?*

Math Teacher Twitter as an Affinity Space

Affinity spaces (Gee, 2004) are a way of thinking about situated learning in terms of the environments where people with common interests come together to work on problems that motivate them. As noted in the literature review (Chapter 2), several studies have applied the affinity space perspective to teacher professional development using Twitter, and some have equated the symbolic space marked out by hashtags with affinity spaces (Greenhalgh & Koehler, 2017; Rosenberg et al., 2016; Staudt Willet, 2019). In this section, the components of affinity spaces, *spaces of social learning*, *content and knowledge*, *portals and generators*, *specialist language varieties*, *shifting strategic identity*, *games and simulations*, are applied to observations

of Math Teacher Twitter in terms of the Twitter discourse features *hashtags used*, *tweet content*, *discursive style*, *values expressed*, *profile content*, and *engagement*.

Spaces of Social Learning

Placing an emphasis on the space (broadly conceived as including virtual and symbolic dimensions) of situated learning is central to the affinity space model. This focus on the learning environment may be particularly important in technology-mediated contexts, such as professional development using Twitter. From the perspective of several studies (Greenhalgh & Koehler, 2017; Rosenberg et al., 2016; Staudt Willet, 2019), the Twitter discourse feature *hashtags used* is a natural starting point for looking at the space in which Math Teacher Twitter occurs. Analysis of the data collected for this study suggests that, when considering Math Teacher Twitter as a space of social interaction, rather than marking out boundaries of the space, hashtags should be thought of as topographic features found within a broader space. Assessing the topics of tweets from the phase-one dataset, tweets that employed the key METHs were more focused in their use of topical terms, but tweets that did not use key METHs still frequently contained topical terms (see Table 4.7 and Table 4.8). Tweets without hashtags may not be as searchable, engage in self-classification, or signal some metameanings that hashtags declare, but are still frequently used by profiles within the phase-one dataset to communicate within a follower-network (see Table 4.6), and should be considered as part of the Math Teacher Twitter space. Looking at *tweet content* in phase-two dataset reveals that while `#mtbos`, `#iteachmath`, and `#mathchat` are markers within a semantic space concerned with math education, `#math` is, when considered on its own, a marker for off-topic spam tweets. A *discursive style* of participatory talk observed with `#mtbos` may be suggestive of people coming together around "solving certain sorts of problems" (Gee, 2004, p. 28), situating it at the heart of what affinity spaces are assumed to provide. In contrast, `#math` sits somewhere on a very fuzzy border between the interior and exterior of the space. When they are used, the key METHs overlap (as illustrated in Figure 5.1) in a way that further suggests that a simple equivalence between a particular set of hashtags and an affinity space would not be appropriate. Rather than something explicitly bounded by hashtag use, Math Teacher Twitter must be conceived as a broader space within which certain hashtags, including the identified key METHs, provide access and help define its contours.

Content and Knowledge

An affinity space is a space of structured content that participants access, move through, and shape. The key METHs (`#mtbos`, `#iteachmath`, `#mathchat`, and (somewhat problematically) `#math`) structure the content of Math Teacher Twitter in a non-obvious way. As topical

markers, these are not clearly indicating different topics and have no overt relationship to each other. Some indications of the structuring functions that these hashtags provide can be observed in how they are used. Looking at *profile text*, the use of `#mtbos` and `#iteachmath` rather than `#mathchat` and `#math` marks content as originating from profiles that are more likely to include explicit identification with "math education" (see Table 5.17 and 5.18). The *engagement* with these hashtags can be interpreted as an indicator of topical relevance, further suggesting that `#mtbos` and `#iteachmath` rather than `#mathchat` and `#math` are on-topic (see Table 5.19). So, while hashtags do not openly declare how specialized the content associated with them is, engagement and profile data associated with hashtag combinations demonstrate how content is stratified through hashtag use.

Portals and Generators

Portals and generators are concepts that are closely linked to the idea of topical content being locatable within the space: portals are aspects of the space that provide access to content, while generators help create content. The Twitter discourse feature *hashtags used* can be associated with both portals and generators within the space of Math Teacher Twitter. An appropriate hashtag acts as a portal in that searching using the hashtag brings those using it to content that is relevant to their interests, and using hashtags appropriately brings participation and engagement to the content that they add to the space. In this way the hashtags also act as generators of content – hashtags mark content that should be considered as part of the space, and also potentially serve to help generate interaction around that content, creating additional content and also increasing its visibility. The phase-two dataset shows that how hashtags function as portals and generators is difficult to reconcile with a view that sees them strictly as topical markers, however. Looking at *hashtags used* in combination with other discourse features such as *tweet content*, and `#engagement` allows for the relative strength of portals to be roughly assessed. The most obviously topical hashtags, `#math` and `#mathchat` do not exhibit the strength of the less obvious `#mtbos` and `#iteachmath`. The `#math` hashtag, in particular, can be characterized as a weak portal, in that searching for this hashtag returns a large amount of spam and less focused content. Yet paradoxically, this hashtag is used frequently and broadly in the initial profiles dataset. The use of `#math` as a generator seems to reside in how it can highlight and express a valuing of the core topic of "math" when combined with other key METHs, rather than in its strength as a portal.

Specialist Language Varieties

The particular topic that an affinity space provides content about will be expressed using specialist language varieties. One of these structuring functions that the key METHs provide is to mark out a broad space of interaction within which more specialized topics can be identified through hashtags that are opaque constructions or concatenations, such as `#alg1chat` or `#apstats`. These, along with other less transparent hashtags such as `#pbl` (problem-based learning) or `#geogebraart` (math art made with the program GeoGebra), are elements of specialized language varieties that are found in the specific context of exchanges about mathematics education. The engagement around these more opaque hashtags (Table 5.20) reveals some dynamics within this space, where more specialized knowledge exchanges gain more attention. In the affinity space context, the Twitter discourse feature *values expressed* can be interpreted in the context of "topics of interest": value is being expressed around particular hashtags because they signal specialized topics of interest to mathematics educators.

Shifting and Strategic Identity

In affinity spaces, participants present aspects of themselves that are relevant to the topic of the space (a portion of their identity *portfolio*), and only optionally present other aspects of their identity. On Twitter, in addition to a unique *handle*, users are encouraged to provide a name, profile text (prompted as "bio"), location, and website. All of these are optional, and there is no requirement to provide accurate (or even factual) information. In this sense, Math Teacher Twitter meets the expectation of affinity spaces for allowing shifting and strategic identity. The Twitter discourse feature *profile text* captures the textual aspect of the Twitter profile. As observed, disclosing an interest or involvement in math and education as part of the profile text is associated with the use of `#mtbos` and `#iteachmath`, and the use of these hashtags may also be seen as a form of identity disclosure in themselves, explicitly emphasizing "I teach math" or "I consider myself a part of the MTBoS." Disclosure of professional identity or personal interests through profile text or hashtags used may represent a strategic way of participating more fully within the space. However, as noted in Carpenter et al. (2019), educators' disclosure of identity on Twitter represents difficult boundary work, and that greater disclosure of some aspects of identity may be associated with privilege (p. 6).

Games and Simulations

Gee (2017) notes that contemporary computer games provide strong *attractors* to online affinity spaces and that the learning that some of these games provide through simulation provides a helpful metaphor for learning in general (Gee, 2004). The appeal of social networking

sites such as Twitter is explained in part by how it provides a *gamified* simulation of social interaction, where real-world social concepts are provided with a measurable score through follower counts, likes, and retweets, as described by Nguyen (2021a):

> Twitter gamifies communication by offering immediate, vivid, and quantified evaluations of one's conversational success. Twitter offers us points for discourse; it scores our communication. And these game-like features are responsible for much of Twitter's psychological wallop. Twitter is addictive, in part, because it feels so good to watch those numbers go up and up. (p. 412)

These "numbers that go up and up" are captured by the *engagement* feature of Twitter discourse. As part of Twitter's gamified social interaction, Math Teacher Twitter is an affinity space which is at the same time a simulation that allows participants to practice "enacting the right sort of identity." Forms of this enactment can be observed through the more specialized hashtags that accompany the key METHs. Some of these hashtags are calls to simulate in-class activities (such as `#wodb`) or out-of-class professional development activities (such as sharing of specific class resources `#alg1chat` and `#apstats`), while others are explicit calls to present an image of idealized teaching behaviours (such as `#tmwk`, and `#teach180`). The gamified communication on Twitter allows for simulated actions that fulfill one of the key criteria that Gee (2004) claims make games effective learning environments: "They create motivation for extended engagement" (p. 74). However, the games that emerge from Twitter's gamified elements are not designed with learning in mind, so may fall short of having the additional connections that Gee (2004) establishes between some intentionally designed games and established learning principles.

Summary

The preceding paragraphs illustrate how features of Twitter discourse observed in Math Teacher Twitter can be interpreted using the *affinity space* model of situated learning. The fundamental idea behind the affinity space concept is that "people learn best when their learning is part of a highly motivated engagement with social practices which they value" (Gee, 2004, p. 77), and studies of teacher use of Twitter has suggested that those who use this for professional development are strongly motivated and see value in the interactions they find there. In looking at both identified profiles of participants (the phase-one dataset), and a corpus of tweets built from identified key METHs (the phase-two dataset), a semantic space of topical content related to mathematics education can be identified on Twitter. Some access points to this semantic space are the key Math Education Twitter Hashtags `#mtbos`, `#iteachmath`, `#mathchat`, and `#math`. These key METHs fulfill the roles of *portals* and *generators* for the content of the affinity space. For participants, Twitter presents an open and accessible interface that does not require

explicit identity declaration and provides gamification of social interaction, elements which allow for simulated interactions that potentially facilitate learning through identity enactment.

Table 6.1
Affinity Space Components and Twitter Discourse Features

component	features
spaces of social learning	*hashtags used*, *tweet content*, *discursive style*
content and knowledge	*tweet content*, *hashtags used*, *profile text*, *engagement*
portals and generators	*hashtags used*, *tweet content*, *engagement*
specialist language varieties	*hashtags used*, *values expressed*
shifting strategic identity	*profile content*, *hashtags used*
games and simulations	*engagement*, *hashtags used*

While the connections drawn in the preceding sections between affinity space components and Twitter discourse features (see Table 6.1) show how hashtags play an important part in understanding Math Teacher Twitter as an affinity space, the description that emerges from the analysis of the phase-two data set suggests a problem with simply defining Math Teacher Twitter as a hashtag-mediated space. While apparently marking relevant content and providing access to it, the key METHs are used within that space in ways that defy explicit identification with particular topics. An evaluative approach to understanding Math Teacher Twitter as an affinity space reveals that hashtags vary in strength when considered as portals and are used in unexpected ways when considered as generators. Because of its complexities, participating in this space requires tacit knowledge in order to access relevant content and to participate in the gamified interactions that generate and modify content. While the affinity space perspective is useful in drawing attention to affordances like hashtags that shape interactions within Math Teacher Twitter, it deemphasizes the cultural (or community) conventions and practices that are the drivers behind how these generic affordances are used.

Math Teacher Twitter as a Community of Practice

Communities of practice (Lave & Wenger, 1991) provide a way of understanding learning as a culturally-mediated process of identity formation. The community of practice model has been used to describe teacher professional development activity on Twitter in a number of studies described in the literature review of Chapter 2 (Britt & Paulus, 2016; Gao & Li, 2017; Larsen & Parrish, 2019). In this section, the identified components of the community of practice model of situated learning, *identity and membership*, *reproduction*, *periphery and centre*, *transparency*, *discourse of practice*, and *legitimacy*, are applied to observations of Math Teacher Twitter described

in terms of the Twitter discourse features *hashtags used*, *tweet content*, *discursive style*, *values expressed*, *profile content*, and *engagement*.

Identity and Membership

From the perspective of Lave and Wenger (1991), learning is a process of identity formation, or equivalently, of attaining membership within a community of practice. One feature of Twitter discourse that provides an indicator for identity and membership is *hashtags used*. Two of the key METHs, `#mtbos` and `#iteachmath`, provide interesting and diverging examples of identity/membership declaration. The direct identity declaration of "I teach math" does not present itself as a statement about the topic of the tweet itself, but rather a declaration of identity and membership in the Math Teacher Twitter community of practice. More subtly, the use of `#mtbos` is a demonstration of insider knowledge that also asserts a claim to membership, and can be interpreted in some cases as a label of the community itself. Rather than describing the topic of the tweet, the inclusion of `#mtbos` may be taken as a simultaneous declaration of who the tweet is directed at, and a claim of membership within that same group. The group-rather-than topic nature of `#mtbos` is illustrated in the *discursive style* of directly addressing MTBoS and using this hashtag to frame questions addressed to the community (see Figure 5.4a and Table 5.14). Users of these two hashtags are more likely to make explicit statements in their Twitter *profile text* that more closely affiliate them with "mathematics education" (see Table 5.17). Viewed through the lens of communities of practice, several Twitter discourse features can be seen as direct and indirect expressions of identity and affiliation with Math Teacher Twitter.

Reproduction

In considering learning as a socio-cultural phenomenon, the community of practice perspective shifts away from the usual attention that is placed on the individual learner and towards the community that is reproducing itself as newcomers become old-timers within an established practice. The peculiar use of hashtags in Math Teacher Twitter traces patterns of reproduction within the community. The non-obvious nature of the *hashtags used* in Math Teacher Twitter (both the `#mtbos` and `#iteachmath` key METHs and other concatenations and opaque constructions) suggest that mechanisms beyond clear topic identification are responsible for hashtags that are predominantly used. Social influence has been identified as a key mechanism through which folksonomies achieve a stable structure (Fu et al., 2010). By imitating the established Twitter behaviours of existing participants, newcomers find their way into interactions that are recognized as legitimate and receive the engagement that the use of recognized conventions provides. As suggested by *engagement* metrics (Table 5.20), including opaque hashtags in a tweet is

associated with increased levels of favorite and retweet interactions. Retweeting, a practice that is shown in the phase-one dataset to be more prevalent among the high reputation associations (see Table 4.3), can be seen as a process by which established *knowledge brokers* sanction and legitimize content, reproducing and reinforcing established symbolic practices.

Periphery and Centre

Membership in a community of practice is not binary: membership is a spectrum that recognizes learners as participating legitimately on the periphery and more experienced practitioners participating along a gradient that leads towards a more central position within the community. The inclusion of more than one hashtag in the queries used to build the phase-two dataset, and particularly the inclusion of `#math` helps to demonstrate one of the boundaries that establish the periphery of legitimate participation in Math Teacher Twitter. The spam tweets associated with `#math` when this hashtag is used without other key METHs provide examples of Twitter content that are structured very differently than those tweets that represent its legitimate use in conjunction with other key METHs. Within the outer boundary of the periphery of legitimate participation, the use of specific hashtags like `#mtbos` and `#iteachmath`, and the use of concatenations or opaque constructions more generally, show greater levels of *engagement*, illustrating varying levels of centrality. Those participants who disclose a more explicit affiliation with mathematics education within their *profile text* also show increased levels of engagement. While some practices are associated with greater centrality, the frequent use of high-legibility hashtags and other markers of broadcast talk are associated with those who are outside the periphery.

Transparency

The tools used within a community of practice may vary in their transparency, a quality that affects how readily those on the periphery can understand how to use these tools and become full practitioners. Among the tools of expression and engagement used in Math Teacher Twitter, the discourse features *hashtags used* and *values expressed* provide examples of varying levels of transparency. It is interesting to note that tensions surrounding transparency are revealed in the use of the apparently redundant `#mtbos` and `#iteachmath`: the `#iteachmath` hashtag was a suggested replacement to the non-intuitive `#mtbos` precisely because it provides a more transparent alternative (Meyer, 2017). The declaration "I teach math" draws a clearer boundary around participation, leading to a greater sense of *legitimate* peripheral participation than can be provided by mere use of the `#mtbos` acronym. The `#iteachmath` draws an implied boundary that potentially excludes some participants, but this exclusion is based on a recognized criterion (teaching math) rather than on somehow knowing the `#mtbos` convention. Analysis of the phase-

two dataset reveals, however, that despite being proposed as a direct alternative to `#mtbos`, the `#iteachmath` tag is frequently used alongside it (see Figure 5.1 and Table 5.1). The use of other *opaque constructions* as hashtags provide further lessons on the transparency, or lack thereof, of community practices. Specialized hashtags used in conjunction with key METHs can be seen as more precisely categorizing the content of a tweet, but they also serve to more precisely categorize the users of the hashtag as people who understand conventions and can use them knowingly. The complex use of hashtags that may fail to be searchable due to overuse, such as `#math`, and hashtags that may fail to find a wide audience due to obscurity illustrates how old-timers in Math Teacher Twitter become aware of how to negotiate various levels of transparency in the tweets they author and search for.

Discourse of Practice

Moving from the periphery to the centre of a community of practice involves, in part, adopting the particular speech of full participants. In Math Teacher Twitter, interactions facilitated by the more opaque hashtags, such as `#apstats`, and `#tmwyk` provide examples of a discourse of practice. Anecdotally, these tweets can be primarily seen as *speech about practice* rather than examples of *speech within practice*. These more opaque hashtags are examples of interactions among participants who are more fully involved and are aware of the obscure hashtags and language used in these interactions. In the context of communities of practice, more opaque hashtags may encode domain-specific knowledge, that not only conveys technical information to insiders but also identifies those who participate more fully from those who are on the periphery. In this way, the *values expressed* feature of Twitter discourse provides indications of group affiliation.

Legitimacy

Legitimacy is a quality that expresses the cultural norms of a community of practice which validate certain activities, ways of speaking, and uses of technology so that learners and practitioners are differentiated from those who are outside the community of practice. The Twitter discourse feature of *engagement* is perhaps the most explicit marker of legitimacy, under the assumption engagement is a sign of community approval. Particular *hashtag use*, *values expressed*, and declarations of membership and identity through *profile text* are associated with greater engagement and may represent other forms of legitimate expression within Math Teacher Twitter.

Summary

The preceding paragraphs illustrate how features of Twitter discourse observed in Math Teacher Twitter can be interpreted using the *community of practice* model of situated learning. Complicating an interpretation of Math Teacher Twitter as a community of practice is the openness of the Twitter platform, which makes it difficult to identify participants as a *community* of educators. As observed with the initial profiles dataset, content and interaction in Math Teacher Twitter comes from teachers, but also associations, initiatives, professional development providers, and other unclassified and potentially unclassifiable participants. However, there is a discernible set of conventions and norms which are linked to greater engagement that suggest a culture, perhaps not identical to a community of mathematics educators, but a community of Math Teacher Twitter participants that can be recognized by their use of these conventions and adherence to these norms. Identity and membership is most explicitly shown in the use of `#mtbos` which names the imagined MTBoS community, and the `#iteachmath` which declares credentials of membership. As new participants adopt conventions, the community is reproduced and participants move from its periphery to its centre. The discourse of practice, which presents itself as a combination of talk concerned with mathematics teaching and learning immersed in Twitter-specific conventions, displays various levels of transparency.

Table 6.2
Community of Practice Components and Twitter Discourse Features

component	features
identity and membership	*hashtags used*, *discursive style*, *profile text*
reproduction	*hashtags used*, *engagement*
periphery and centre	*hashtags used*, *tweet content*, *engagement*
transparency	*hashtags used*, *values expressed*
discourse of practice	*hashtags used*, *values expressed*
legitimacy	*engagement*, *hashtags used*, *profile text*

Lave and Wenger (1991) distinguishes between the *learning curriculum* of what is actually reproduced within a community of practice and the *teaching curriculum* of what members may claim their community is attempting to instill in its membership. The learning curriculum that is observable through the phase-two dataset suggests that Math Teacher Twitter encourages those who move from the periphery to its center to learn the specialized language of mathematics educators (at least as it is interpreted in the dialect of Twitter's concatenations and acronyms). This process also calls for participation in sharing and demonstrating best practices (as determined by other participants), again indicated by the use of specialized hashtags (such as course-specific hashtags like `#apstats`, short forms for teaching approaches like

#thinkingclassroom, or participation hashtags such as #tmwyk). Learning how to speak the language of math education, and sharing resources around particular topics and approaches, is potentially aligned with teaching curriculum that would be expected through conventional professional development. Although seemingly in sympathy with the same kinds of learning that one would expect from real world professional development, these same observations illustrate how learning in Math Teacher Twitter is tied to Twitter-specific conventions and practices, particularly the gamified elements of social interaction on the platform, that are essentially unrelated to mathematics education.

Interpretations of Twitter Discourse Features

The preceding sections presented interpretations of the analysis of the phase-two dataset from the perspective of affinity spaces and communities of practice. These interpretations started from the standpoint of the identified components of the two models and provided narrative descriptions that referenced various features of Twitter discourse. This section attempts to look in the opposite direction by noting the different ways in which the models interpret each Twitter discourse feature.

Hashtags used. The interpretation that hashtags have generally been given by researchers applying the affinity space model is that they help identify the topic of interest. This interpretation is problematic when it comes to more opaque hashtags such as #mtbos and #iteachmath as they do not specify the topic directly. The community of practice model would see hashtags as a culturally defined artifact whose use is more of a signal of identity and membership. Both interpretations would see hashtags as facilitating associations but would differ in explaining the mechanism. An affinity space interpretation would suggest that hashtags (perhaps through a negotiated process) help identify topics, while a community of practice interpretation that the use of hashtags identifies community members.

Tweet content. At the level at which this study analyzed most tweet content using term frequencies, subtle distinctions were not observable. To the affinity space model, these frequent terms are an indicator of the topic that the space is concerned with. The community of practice model notes that "ways of speaking" are more essential than obvious content (Lave & Wenger, 1991, p. 106). Because of this, from the community of practice perspective, the frequent terms (and perhaps more strikingly highlighted hashtags within the tweet content) provide examples of imitation, repetition and convention, or community reproduction.

Discursive style. The discursive style of a tweet can be classified as either participatory or broadcast. From an affinity space perspective, this can be an indicator of whether the tweet seems to be about working together on problems of mutual interest, or something more off-topic. From a community of practice perspective, participatory exchanges are associated with identity formation, and perhaps an indication of the movement from the periphery to a more central position within the practice, while broadcast talk is found outside the periphery of legitimate participation.

Value expression. Hashtags that are used within a body of a tweet, rather than appended at the end as typical subject classifiers, and particularly hashtags that cannot help with search (due to overuse or ambiguity), draw the attention of readers precisely because they are not enacting the expected role that hashtags generally play. Very obscure or idiosyncratic hashtags may draw the attention of participants who may have not explicitly searched for the hashtag but recognize it as some other signal of meaning or affiliation. From the affinity space perspective, these may be markers of a key topic or specialized term. In a community of practice interpretation, these are seen as expressions of shared values or insider knowledge.

Profile content. In both the affinity space and community of practice models, profile content can be seen as identity disclosure. Affinity spaces take the perspective that identity disclosure is something that is flexible and strategic, something that users can flexibly do as they build a shape-shifting portfolio of identities. The community of practice model sees identity formation as central to the learning process, and would perhaps interpret more direct claims to an identity as a mathematics educator as one way of being located more firmly within the community of practice.

Engagement. Both tweets and profiles can report different levels of engagement, through Twitter constructs such as likes, retweets, and follower counts. From an affinity space perspective, engagement may be seen as an indicator of topicality: more on-topic tweets will receive more engagement, as will the profiles that provide those tweets. Engagement may also be seen as part of a game-based approach to learning, providing feedback to participants in an affinity space on how well they are navigating the simulated social learning environment that Twitter provides. From a community of practice perspective, engagement metrics provide an assessment of legitimacy and define the gradations between the centre and the periphery of the community.

Complementary or Contradictory Interpretations

The preceding sections illustrate how both the affinity space and the community of practice models offer interpretations of Twitter discourse that link the theoretical concepts of each

model to concrete observations of Math Teacher Twitter. In certain respects, these interpretations may not be mutually exclusive, and the different interpretations offered by these models can be thought of as differences in emphasis. However, when looking at specific questions raised by the observations of Math Teacher Twitter from the phase-two dataset, these two models can potentially provide perspectives that are not easily reconciled.

An interesting observation from the analysis of the phase-two dataset is that the less legible hashtags `#mtbos` and `#iteachmath` show the greater levels of engagement than the more conventional `#mathchat` and `#math`. How does this observation fit into the interpretations of Math Teacher Twitter offered by the affinity space and the communities of practice models? While perhaps not completely irreconcilable, the two perspectives may provide different interpretations: the affinity space model suggests that participants are *pushed* towards these obscure hashtags in an effort to stay on topic, while the community of practice model suggests that participants are *pulled* towards these in an effort to establish a distinct group identity.

How does the affinity space model lead us to understand obscure hashtag use in terms of a push away from off-topic content? The affinity space model suggests that we look at how people come together over topics they have an affinity for, rather than groups they have an affiliation with. The spam associated with `#math` presents a problem with using this explicitly topical tag as a topic indicator and provides a potential explanation for the use of more obscure hashtags, such as `#mtbos`, in terms of the affinity space model's focus on topicality. An understanding of "hashtag formation" that privileges the idea of topicality (rather than identity) as the main driver for Twitter interaction, would see the off-topic spam associated with `#math` and other more obvious hashtags as pushing participants to use less obvious topic markers, such as `#mtbos`, in order to identify on-topic tweets. In this view, without spam, more obviously topical hashtags such as `#math` would be directly useful as portals and generators for the Math Teacher Twitter affinity space, and it is the pressure of off-topic content that leads to more obscure hashtag use.

As Math Teacher Twitter is an emergent rather than a designed phenomenon, how are these more obscure hashtags chosen? The community of practice perspective would suggest that there is a pull towards the use of these shibboleths as markers of membership and identity. While the idea of finding a better way to get together around a topic provides some motivation for the use of obscure hashtags such as `#mtbos` and `#iteachmath`, these conventions can only develop amongst a group that is affiliated with each other in some way, and concepts from the community of practice model provide a way to explain the dynamics of how these conventions arise. The community of practice model would suggest that the use of more obscure hashtags is energized because they provide a sense of distinction between those who identify as members of the community and those that do not. For this purpose, some obscurity of language is desirable in itself and is not just a result of other pressures. A community of practice view of

Math Teacher Twitter would predict the emergence of obscure hashtags, such as `#mtbos`, even if spam-avoidance was not a concern for participants.

Hashtag selection and use, and other processes that are operating within Math Teacher Twitter, can be overdetermined: the push away from non-topical spam and the pull towards community identification may be occurring at the same time, with both models offering valid explanations. However, the significant difference in perspective offered by these models is worth noting and suggests that adopting a single perspective on the phenomenon of Math Teacher Twitter can miss some of its important aspects.

Chapter 7

Discussion and Conclusions

The two research questions addressed in this study were concerned with how we can better understand informal math teacher professional development on Twitter, from the perspective of discourse and through the lenses of particular models of situated learning.

> *RQ 1: What are some of the important characteristics of the discourse associated with mathematics educators' informal professional development on Twitter?*
>
> *RQ 2: How do theories of situated learning, such as the community of practice and affinity space models, help us understand the informal professional development practices of mathematics teachers on Twitter?*

In order to answer RQ1, specific features of Twitter discourse were assessed using established methods such as reputation index along with new methods such as measuring hashtag placement and legibility. The portrait of Math Teacher Twitter that emerged from this analysis is one where tweets about mathematics and education can be identified using a variety of hashtags, with `#mtbos` and `#iteachmath` being associated with the strongest measures of relevance and engagement among those queried for. As anticipated by linguistic studies of hashtag use, the use of hashtags in Math Teacher Twitter is seen to be complex and serves other purposes than direct topic classification (Zappavigna, 2012). The *other* and *mutual* orientation of `#mtbos` and the *self* referencing `#iteachmath` reinforce the suggestion from Staudt Willet (2019) that tweets can be distinguished based on their purpose and suggests that hashtags may play a role in how participants frame those purposes. The discursive style of Math Teacher Twitter was found to exhibit varying degrees of participatory talk, and again in this regard hashtags are found to perhaps play a role. It is suggested that `#mtbos`, with its ability to be used addressively and to allow for the conception of an imagined community, helps facilitate interrogative statements and

participatory talk. As suggested by Carpenter et al. (2020), spam was also found to be a part of Math Teacher Twitter, where tweets that use #math in the absence of other key Math Education Twitter Hashtags (#mtbos, #iteachmath, #mathchat) exhibit characteristics of spam and broadcast-talk. Examples within Math Teacher Twitter illustrate how broad hashtags such as #mtbos are used together with hashtags such as #apstats or #thinkingclassroom to narrow down topics or highlight common values. Disclosure about topical interests within Twitter profiles, measured in ways similar to personal disclosures as in Carpenter et al. (2019), varies among Math Teacher Twitter participants but can be associated with hashtag use and engagement. Considering these observations, it is apparent that features of Twitter discourse such as *hashtags used, tweet content, discursive style, value expression, profile content,* and *engagement* are useful indicators of different approaches to using Twitter for professional development and present helpful ways pathways towards understanding the dynamics of Math Teacher Twitter.

To address RQ2, the community of practice and affinity space models were described in terms of conceptual components that could be compared with Twitter discourse features. Applying the conceptual components of the models of situated learning in a critical way demonstrated that these models provide viable but divergent interpretations of the phenomenon of Math Teacher Twitter. At a high level, hashtag use can be seen to provide an affinity space for individuals interested in topics related to mathematics education, similar to how more popular hashtags such as #edchat facilitate this (Carpenter & Krutka, 2014; Staudt Willet, 2019), or how state-education and course-specific hashtags have been shown to do so (Rosenberg et al., 2016). The affinity space concept captures the highly motivated and personally directed involvement that participants in Twitter-based professional development often report, and the discourse features of Math Teacher Twitter that were observed in this study map on to key components of the affinity space model. For example, the affinity space model allows us to interpret the hashtags used in Math Teacher Twitter as *portals and generators* of various strengths. At the same time, the gradients of participation and engagement that are observed across Math Teacher Twitter in this study are consistent with the core understandings provided by the community of practice model of situated learning. Certain conventions (the use of #mtbos in particular ways, for example) are expressions of *legitimate participation* that allow participants to situate themselves at more central positions within the community. Providing a way to understand more detailed mechanisms of interaction, a critical application of the community of practice model of situated learning helps explain the specific ways that Math Teacher Twitter maintains and reproduces itself.

Answering both R1 and R2 reveals that Math Teacher Twitter is a phenomenon that involves complex discourse features, which can be interpreted in ways that can seem both complementary and distinct when viewed through different models of situated learning. In this chapter, I will describe how in answering these questions, this study contributes to our understanding of

the professional development of math teachers on Twitter, how it may be helpful to educators in approaching professional development in this way, and how future research might approach similar questions.

Contributions to Research Methodology

By taking a two-phased approach to first identifying hashtags and then using these hashtags as a means of building a corpus of tweets to analyze, this study helped to illustrate several aspects of hashtag use that have methodological implications for studies that look at hashtag-mediated participation on Twitter:

1. A set of profiles can be used to identify key hashtags that are associated with exchanges that are focused on a particular topic area. Hashtags identified in this way do not necessarily provide exclusive access to that topic area, but queries that use these hashtags may provide access to topical exchanges. In particular, `#mtbos`, `#iteachmath`, and `#mathchat` emerged as key Math Education Twitter Hashtags based on this analysis.

2. Mere frequency of on-topic use among selected profiles is not sufficient to establish a hashtag as providing reliable access to on-topic conversations. The `#math` hashtag was identified as a key METH based on frequent and broad use across an initial set of profiles, however when used in general queries, it was shown to be predominantly associated with spam tweets.

3. Hashtags that are discovered to be associated with a topic, such as the key METHs in this study, may be used in combinations in ways that can seem redundant from a topic-labelling perspective. From a topic-labeling perspective, combinations of `#mtbos`, `#iteachmath`, `#mathchat` and `#math` can seem repetitive. When these hashtags are seen to fulfill other roles, or when the possible repetition is understood as a linguistic strategy, these uses can be better understood.

4. Hashtags can be used to explicitly address an imagined community, such as when the Math Twitter Blogosphere is directly addressed through `#mtbos`. Addressive use may be something that some hashtags allow more readily than others, and hashtags that present the option to be used this way may invite more interrogative tweets and facilitate participatory talk.

5. As noted, some hashtags used in topical tweets, such as `#math`, when used as search terms may return a large proportion of spam tweets. These hashtags may at times be used intentionally in non-spam content to highlight important terms within the tweet or to signal

value. The knowing use of these hashtags may represent an attempt at signalling affiliation with an imagined audience, while more arbitrary use of these tags potentially signals an almost opposite discursive style of broadcast talk.

6. Hashtags may be used more to label the identity of the user than the topic of the tweet, such as the explicitly self-referential `#iteachmath` or the implicit claim to membership in the use of `#mtbos`.

7. Hashtags can encode an instruction for how a tweet should be read. The hashtag `#wodb` ("which one does not belong") explains that the tweet will include references to a set of objects that may all be members of overlapping sets, and the reader is invited to present an argument as to why one object does not belong. A tweet that includes `#tmwyk` ("talking math with your kids") should in most cases be read as a personal anecdote by a mathematics educator about math-talk with their own children.

8. Specific topic-narrowing hashtags can be included with broader hashtags, so the hashtag `#cgi` along with `#mathchat` allows the topic of cognitively guided instruction to be introduced in the larger context of a `#mathchat` facilitated discussion.

The key methodological implication of these observations is that hashtags should not be viewed strictly as topical markers, even in the folksonomic sense. Instead, they must be viewed as contributing to the metamessage of a tweet, and they can involve complex uses. Ways of beginning to understand these complex uses include looking at how the hashtags are composed (as single words, concatenations, acronyms or opaque constructions), how they are combined to signal repetition or differentiation, and how they are placed within a tweet in order to fulfill roles as addresses, highlights, or subject classifiers.

A broader appreciation of hashtag use is not uncommon in linguistic studies of Twitter, such as Zappavigna and Martin (2018) or Page (2012), but is less frequently found in studies of teacher professional development on Twitter, which tend to associate specific hashtags directly with topics (as in Greenhalgh & Koehler, 2017), or have assumed that they directly map on to an affinity space or community (as in Adjapong et al., 2018). Linguistic studies of Twitter discourse suggest the use of metrics such as hashtag legibility, which in this study has been shown to be helpful in describing hashtags and how they are used. Computational methods that allow for analyzing Twitter discourse for formal linguistic features, and an appreciation that affordances like hashtags can play complex roles in conveying meaning, should allow future studies to ask and answer more nuanced questions about educators' use of participatory media for professional development.

Contributions to Theoretical Perspectives

Applying two models of situated learning to the observations of Math Teacher Twitter allows for reflection on the differences in perspective that each model offers. In this section, I will discuss how while the affinity space perspective does not resolve the difficulties of membership that the community of practice model presents, the two models do provide distinct and potentially complementary perspectives of Math Teacher Twitter.

The openness and anonymity of Twitter and the problem of under-participation (see Chapter 4) make it difficult to provide a straightforward membership definition for purported communities of practice that may be using the platform. Affinity spaces present a potential solution to this problem, as Gee (2004) explains:

> If we start with the notion of a "community" we can't go any further until we have defined who is in and who is not, since otherwise, we can't identify the community. Yet it is often issues of participation, membership, and boundaries that are problematic in the first place. . . . I suggest that the problem here is trying to start with a label (like community of practice) which looks like a label for a group of people, a group which must then be identified in terms of its "members." What I want to suggest instead is that (at least sometimes) we start with "spaces" and not groups. (p. 78)

The assumption that hashtags facilitate the topical classification of tweets has led some researchers to assert, as Staudt Willet (2019) does, that on Twitter "affinity spaces rely upon hashtags as the primary organizing feature" (Staudt Willet, 2019, p. 274), or to go further and identify hashtags as defining affinity spaces (as in Rosenberg et al., 2016). If hashtags provide a way of defining affinity spaces based on the topic they are concerned with, then the claim made by Gee (2004) is realized, and a clearer way of talking about situated learning that avoids the imprecision of the community of practice concept has been found.

Looking at Math Teacher Twitter, however, reveals that hashtags (in this case) do not fulfill the promise of making boundaries any easier to discern. Instead, multiple hashtags, including opaque constructions and concatenations, are combined and used in a variety of ways with little obvious connection to the topic that the space purports to be concerned with. Because hashtag use is complex and socially negotiated, the problem of identifying how it may be an organizing feature of a space is exactly symmetrical to understanding the identity and membership contestation that goes into legitimizing particular hashtag use. Consequently, the problem of labelling the space is identical to the problem of understanding the membership rules of the community within that space. In contexts like Math Teacher Twitter, if the affinity space model simplifies by re-framing membership boundaries as spatial boundaries, this is done by ignoring the subtleties of hashtag use and other practices that govern admissibility within the space.

The affinity space model succeeds in providing a high-level description of Math Teacher Twitter as a virtual space where people with an interest in mathematics education can find and share content, interact, learn, and potentially grow as professional mathematics educators. It may be that avoiding the language of communities of practice is helpful in developing a preliminary approximation to describing Math Teacher Twitter by establishing the rough contours of the space in which it can be observed. Pointing out the *portals* that can be used to access this space, and the *generators* that help with content creation is a useful way to begin to understand this phenomenon. However, to understand the mechanisms that drive what is occurring within Math Teacher Twitter, concepts from the communities of practice model of situated learning should be brought to bear. Affiliation plays at least as significant role as affinity in shaping the contours of the space of Math Teacher Twitter, or in determining who can claim membership.

The affinity space model, inspired as it is by contemporary online environments, draws attention to certain important characteristics of Math Teacher Twitter. In particular, the voluntary disclosure of identity and the gamified and simulated nature of the interactions on Twitter resonate with identified components of the affinity space model (*shifting and strategic identity*, *games and simulations*). However, looking at the problems that surround identity disclosure on Twitter more deeply reveals that identity disclosure can be an indicator of privilege (Carpenter et al., 2019), which complicates the assertion that participation in affinity spaces should be free from constraints arising from personal identity (Gee, 2004, p. 85). In contrast, the community of practice model foregrounds problems of identity, providing a critical perspective on how identity is negotiated and expressed in terms of position within the community. In the context of Math Teacher Twitter, this perspective allows identity expression to be recognized not only in the "voluntary" disclosures of profile texts, but also in how community conventions (such as particular hashtag use) are used and understood.

If applied without attempts at over-simplification, the affinity space model can provide helpful preliminary descriptions of situated learning that, when investigated critically, will ultimately call upon the perspective offered by the community of practice model. Finding ways to describe the technology-mediated context of Math Teacher Twitter is central to understanding the professional learning it may facilitate, and affinity spaces provide a way of describing and talking about this context. At the same time, retaining the critical perspectives offered by the community of practice model helps deepen this understanding.

Implications for Practice

The methodological problems faced by a study of Math Teacher Twitter mirror in interesting and instructive ways the practical problems faced by educators attempting to use Twitter to

further their professional development. The findings of this study bring some of the key features of the discourse of Math Teacher Twitter to light, and knowledge of these features can help educators understand the phenomenon more clearly. The approaches to interpreting Math Teacher Twitter as an affinity space or community of practice (applied here at a macro scale) can potentially help educators evaluate their participation in this form of professional development.

Educators seeking to use Twitter in professional development should be aware of the *vocabulary problem* that makes relevant hashtags difficult to identify. In the case of Math Teacher Twitter, this is seen in how somewhat obscure hashtags, such as `#mtbos` and `#iteachmath` provide greater access and engagement compared to `#mathchat`, and how `#math`, when used indiscriminately, is associated with spam. It is also shown in how usage around more specialized tags, including tags that signal certain kinds of engagement, are used. The *participation problem* provides a reminder that most educators who observe, and perhaps learn, from Math Teacher Twitter, do so without contributing significantly to its content. Most of the content is provided by "superusers" who likely have invested a significant amount of energy into participation. The participation problem means that merely following other teacher profiles will not necessarily provide access to Math Teacher Twitter. Phase-one of the current research project involved obtaining tweets from selected profiles, and phase-two involved querying using hashtags observed among these profiles; a similar approach of following identified strong contributors and attending to the hashtags they use is a strategy that educators wishing to access Math Teacher Twitter can use as well.

Participants in Math Teacher Twitter identify themselves as members of the community, or as interested contributors within the space, in several ways. Educators should be aware that their profile text and how their tweets express a discursive style or express value are important indicators of their identity and intent. Adopting a participatory style of discourse, rather than a broadcast style, and highlighting shared values or interests is associated with stronger levels of engagement.

Understanding Math Teacher Twitter as an affinity space or a community of practice may help educators decide if it represents a viable form of professional development for them. Ultimately, a personal evaluation can be framed around questions proposed by the affinity space model such as "does this space help me solve problems I am interested in?" and "what is motivating me to participate in this space?" At the same time, the community of practice model prompts other questions, such as "is what this community legitimizes consistent with authentic practice?" and "what does it mean to be on the periphery or at the centre of this community of practice?" The current study does not answer these questions but suggests that critical applications of models of situated learning can be applied to Math Teacher Twitter.

Limitations of this Study

The current study looked at the phenomenon of math educators' use of Twitter for informal professional development, or Math Teacher Twitter, from two perspectives: the perspective of Twitter discourse features and the perspective provided through two models of situated learning. The analysis from both these perspectives leaves much room for extension. In addition, the two-phased approach to obtaining the data can also be refined in future studies of similar questions.

While some important aspects of Twitter discourse and metadata were included in this study, some important features were omitted. A key measure of social capital formation, and also an indicator of participatory talk, is the explicit use of *mentions* in tweets (Rehm & Notten, 2016). Mentions can arguably be included as a measure of addressivity (and participatory talk), engagement, and centrality or status, and provide another example, along with hashtags, of a Twitter affordance that can help identify meta-meaning within a tweet. While some simple formal linguistic measures were included in this study, for example, frequencies of interrogatives and question marks, other formal linguistic features could also be identified and used as markers of discursive style and other engagement strategies. Linguistic features that can be potentially applied here include rough measures of complexity, such as the number of words used and average word length, but can also include more subtle measures. Another frequently applied measure, particularly in social media, is the use of sentiment analysis, which uses content and linguistic structure to classify statements as having positive or negative emotions. Going beyond linguistic features, to evaluate the non-textual content of tweets (links to websites, links to memes and images, use of emojis), is perhaps becoming more important as participatory media becomes more visual and less textual.

Two essentially new techniques were applied as part of the Twitter discourse analysis: assessment of hashtag placement and hashtag legibility. Both of these techniques could be further refined. In the current study, the placement of hashtags was evaluated using a rough measure of position within the tweet. A more elaborate parsing strategy than the one used here would be able to more accurately assess those hashtags that are appended at the tail of a tweet and differentiate these from those within the head or body. A more subtle approach here would allow for clearer identification of spam tweets, for example. A further refinement of the concept of hashtag legibility could lead to better classification of those tags that the current study classified broadly as *opaque constructions.*

The phase-two data that was the basis of the analysis of Math Teacher Twitter was obtained from hashtag-based queries using the Twitter API. While hashtag-based queries are a recognized way to access topical exchanges on Twitter, another key way that content is generally

provided to Twitter users is through their friend network (the list of profiles they follow). An interesting line of enquiry would be to compare the view of Math Teacher Twitter that is obtained through hashtag-based queries with one that looks at the friend networks of participants. This would require the development of strategies for obtaining relevant and representative friend network data. One possible approach would be to pursue a third phase of data acquisition, to identify profiles that are most followed by Math Teacher Twitter participants, and generate a phase-three dataset based on the tweets from those profiles.

In assessing how theories of situated learning help us understand the Math Teacher Twitter phenomenon, several key components were identified within the affinity space and community of practice model. For affinity spaces, the components identified were *spaces of social learning*, *content and knowledge*, *portals and generators*, *specialist language varieties*, *shifting strategic identity*, and *games and simulations*. For communities of practice, the components identified were *identity and membership*, *reproduction*, *periphery and centre*, *transparency*, *discourse of practice*, and *legitimacy*. This approach helped facilitate comparisons between the model components and specific elements of Twitter discourse. The process of identifying these components could be further refined, leading to the generation of more comprehensive descriptions. Two possible refinements would be in the directions of consistency and completeness. A process of comparing each component with other identified components to help ensure that they do not directly contradict each other would help ensure the consistency of the overall model. While it might not be possible to create a truly complete list of components of a theoretical model, an improvement would include a process to identify significant gaps in the descriptions these components allow to be generated.

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