

Inventing Twitter: An Iterative Approach to New Media Development

IGNACIO SILES¹
Northwestern University

This article analyzes the creation of Twitter by developing an iterative approach that accounts for feedback loops between developers and users, sequences of interaction between these actors over time, and the various identities that media technologies enact during these processes. To implement this approach, the article integrates studies of remediation strategies, analyses of the role of users in shaping technological change, and scholarship on the multiplicity of technological objects. This approach enables theorizing about novel processes of new media development characterized by the interweaving of production and use activities. It also expands the heuristic reach of established approaches to new media development (namely, work on remediation and user agency). The theoretical implications of this approach are discussed.

Keywords: agency, appropriation, enactment, intermediation, iteration, materiality, media change, microblogging, new media, remediation, Twitter, users

The creation of Twitter illustrates contemporary processes of technological development where production and use activities are constantly and variously interwoven. An increasing number of studies reveals that production and appropriation dynamics are more interconnected in practice than previously described in many scholarly accounts (Boczkowski & Siles, in press; Hyysalo, 2010; Williams, Stewart, & Slack, 2005). By studying the case of Twitter's invention and early development processes, this article seeks to contribute to current theorizations of the links between the production and use of media technologies.

I argue that studying the creation and early development of new media requires considering the role of both developers *and* users, how they interact and enact media technologies, and how these interactions and enactments lead to particular patterns of technological development. To make sense of

¹ I thank Ken Alder, Pablo Boczkowski, and danah boyd for their invaluable guidance and suggestions. I received helpful feedback from Lindsay Fullerton and from participants at the doctoral colloquia organized by the Media, Technology and Society and the Science in Human Culture programs at Northwestern University. I also thank the journal editor, Larry Gross, and the anonymous reviewers for their outstanding suggestions.

Ignacio Siles: isiles@u.northwestern.edu

Date submitted: 2013-01-04

Copyright © 2013 (Ignacio Siles). Licensed under the Creative Commons Attribution Non-commercial No Derivatives (by-nc-nd). Available at <http://ijoc.org>.

these processes, I posit the notion of “iteration.”² This concept affords three analytic advantages. As an *action*, iteration points to sequences of interaction between actors such as developers and users. The notion of the “feedback loop” described by Hayles (2005) captures these exchanges and how they materialize into specific technological features. As a *process*, iteration invites an account of the repetition of feedback loops. It thus encourages tracing sequences of interaction between developers and users over time. Finally, as a *product*, iteration suggests that media technologies can be instantiated or materialized in many ways. This means not only that media technologies are “constantly in the process of reformulation” (Balsamo, 2011, p. 35) but also that developers and users can variously enact them. Together, these three insights further theorize interconnections and crossovers between the identities of producers and users that can be fundamental for the development of media technologies.

I develop this iterative approach by carefully examining how production and use activities were interwoven during Twitter’s early development. Drawing on interviews with Twitter’s creators and early users, Web archiving techniques, and traditional archival research, this article discusses the potential of this approach for theorizing contemporary patterns of new media development and for expanding the analytical reach of established theoretical frameworks, which I discuss next.

Theoretical Considerations

To make sense of Twitter’s invention process, this study brings together three bodies of theoretical work: studies of technological production and design dynamics, particularly remediation strategies; analyses of the role of users in shaping technological change; and a strand of scholarship in science and technology studies (STS) that focuses on the multiplicity of technological objects.

Studies of Remediation and Intermediation

To produce and design novel technologies, developers typically draw on previous practices and artifacts. Bolter and Grusin (1999) theorized this dynamic through the lens of “remediation”—that is, how a singular medium repurposes, refashions, and rehabilitates the “techniques, forms, and social significance” of previous media (p. 65). Remediation is “the making of new media forms out of older ones” (Bolter & Gromala, 2003, p. 80). According to Bolter and Grusin, remediation is enacted through two mutually dependent cultural logics: immediacy, or the assumption that media can provide a direct way to experience reality; and hypermediacy, or the fascination with media’s means of representation through which media produce reality. A new medium can thus remediate another by reproducing the way it represents content and reality (instantiating the logic of immediacy) or by highlighting their discontinuities (illustrating the logic of hypermediacy).

Some scholars have argued against the assumption of linear causality that underlies Bolter and Grusin’s framework. Hayles, for example, prefers the notion of “intermediation,” which she defines as the process “whereby a first-level emergent pattern is captured in another medium and re-represented with the primitives of the new medium, which leads to an emergent result captured in turn by yet another

² This approach is not to be confused with the “iterative design” method (Balsamo, 2011).

medium, and so forth" (Hayles, 2007, p. 100). Hayles suggests that media are interconnected by feedback loops that express various forms of remediation. The materiality of media technologies is a key in Hayles' theory of intermediation. Materiality, according to Hayles, "emerges from the dynamic interplay between the richness of a physically robust world and human intelligence as it crafts this physicality to create meaning" (Hayles, 2002, p. 33).

Theories on remediation and intermediation make possible an examination of how developers employ meaning-making strategies that have characterized previous media technologies and mobilize materiality to enable these strategies. However, research in this tradition has concentrated primarily on production dynamics and has not significantly theorized how users participate in remediation processes. To supplement these perspectives, I turn to work on the user-technology interaction.

Interdisciplinary Work on User-Technology Interaction

Scholars from various fields have shown that technological development does not stop when artifacts are designed and produced, but that users can play an active role in shaping the paths of the stabilization of media technologies (Fischer, 1992). In STS research, the user-technology interaction has gained "renewed interest" over the past 15 years (Wajcman & Jones, 2012, p. 676). Oudshoorn and Pinch (2003) thus speak of a "turn to the users" (p. 4) in STS. In this body of work, users are typically conceptualized as agentic actors who can establish new pathways of technological development by attributing new meaning to media technologies, by using them in unexpected ways, and by altering the material structure of artifacts to enable these new interpretations and uses (Eglash, 2004).

More precisely, Orlikowski (2000) argues that the "structures of technology use are not fixed or given, but constituted and reconstituted through the everyday, situated practices of particular users using particular technologies in particular circumstances" (p. 425). She refers to these singular use dynamics as "technologies-in-practice," which she defines as "specific structure[s] routinely enacted as we use the specific machine, technique, appliance, device, or gadget in recurrent ways in our everyday situated activities" (2000, p. 408). Orlikowski deploys the notion of "enactment" (as opposed to "appropriation") to suggest that technologies are "never fully stabilized or 'complete'" (2000, p. 412). Instead, they are open to a set of different uses shaped by the specific features of artifacts, the symbolic frames that inform their interpretation, the role of intermediaries, and the singular contexts in which use activities take place.

STS Analyses of Multiplicity

Like Orlikowski, scholars interested in issues of multiplicity in STS have employed the notion of enactment to argue that the realities and identities of technological objects are variously performed (Law, 2002, 2008). Researchers in this tradition contend that realities are not constructed—a term that evokes a sense of finality—but constantly crafted in specific situations. Thus, Law (2008) writes, "[Various] realities (including objects and subjects) and representations of those realities are being enacted or performed simultaneously" (p. 635). To better understand how these enactments take place, scholars have focused on practices. This focus, Mol (2002) maintains, allows identifying the mechanisms through which different enactments are coordinated (thus producing the sense of a single reality) or distributed. In this view,

technological objects seem to be a singular, stable reality only when the variety of enactments and practices constituting them is bracketed. In contrast, their realities multiply when various enactments are examined.

This study brings these three theoretical threads together to analyze key processes in the contemporary development of media technologies. Theories about remediation dynamics invite an investigation of new media production as a process shaped by the reproduction of certain meaning-making strategies and the materiality that makes them possible. Work on user agency enables an analysis of how media technologies also change in response to shifting interactions between users, developers, and technologies. Research on multiplicity invites recognition of the various identities that a media technology such as Twitter can have and the practices through which these identities are enacted during both production and appropriation activities.

To bring these frameworks together, I draw on previous scholarship that has sought to articulate production and use activities (Boczkowski, 2010; Boczkowski & Siles, in press; Hyysalo, 2010; Ross, 2012; Williams et al., 2005). This body of work has greatly contributed to our understanding of how development and use practices are related throughout the life cycle of media technologies and has blurred the distinctions between developers and users as conceptual categories. Millerand and Baker (2010) have noted that “users and developers are not stable entities; they tend to adopt multiple roles that are constantly evolving throughout information development system processes” (p. 152). In practice, they contend, there are “crossovers and emergent roles in-between” these categories (p. 156). The iterative approach deployed to make sense of the invention of Twitter contributes to this body of work in two main ways: It enables theorizing about novel processes of new media development that are characterized by the constant interweaving of production and appropriation activities, and it helps us rethink existing approaches to new media development—namely, work on remediation and theories on user agency. I elaborate on these theoretical contributions in the conclusion of the essay.

Research Design

This study combined various research methods: interviews, Web archiving techniques, and traditional archival research. This research design allowed for combining methods with alternative strengths and considering diverse sources to triangulate the data (Denzin, 1978).

As part of a larger study of the historical development of Web applications for self-expression, I conducted 45 interviews with key actors, including some of Twitter’s creators and early users. Following methods for ethnographic interviewing (Spradley, 1979), I invited interviewees to describe the processes that led to the production of this software application and to interpret its historical development. I then asked early users to give an account of their early use practices and how these practices have varied over time. I conducted most interviews in person, although some were completed by telephone, Skype, or e-mail. Interviews lasted an average of 58 minutes. I recorded each interview and transcribed it entirely.

In addition, I examined online sources, such as Twitter accounts, news outlets, blogs, and discussions on forums. I also analyzed Twitter’s early configuration and development by examining

different versions of its Web interface that were available on the Internet Archive's "Wayback Machine." To make sense of these data, I employed Web archiving techniques developed primarily by Foot and Schneider (2010). Once I had identified relevant sources on the Web, I analyzed them in two ways: (1) I categorized them—that is, I ascertained their main features and types of content; and (2) I annotated them by producing metadata that could allow for the interpretation of both their core material features and kinds of content. Finally, I conducted archival research of numerous primary sources, including newspapers, magazines, and interviews and conference presentations given by Twitter's developers in various contexts.

Using grounded theory (Corbin & Strauss, 2008), I examined the data collected through these methods and developed various categories to account for the main concepts and relationships found in the data. I situated these categories within the wider context in which the invention of this tool unfolded, particularly the culture of the Bay Area. As this process unfolded, I developed an interpretive framework for making sense of Twitter's invention and early development that accounted for the practices and roles of both developers and users. Once theoretical saturation had been reached, I returned to the raw data to verify this framework.

The Invention and Early Development of Twitter

To understand the iterative process through which Twitter was created, I analyzed how developers conceived this application, how they enacted it in a multiplicity of ways, and how users shaped this development process through feedback loops and appropriation practices. The discussion is organized around four processes: the conception, production, launch, and early use of Twitter.

Conceiving Twitter

Twitter first developed as a side project within a small company devoted to building audio Web applications. Early in 2005, Odeo, a small start-up company cofounded by Noah Glass, developer of the Audioblogger service, and Evan Williams, cocreator of the Blogger software, worked to build a subscription-based program that could allow users to find, download, and record audio files through a directory (a set of practices known as podcasting). Williams decided to invest in this start-up after his departure from Google in 2004. Odeo provided Williams with an opportunity to pursue novel projects that seemed more difficult to develop at Google. He brought with him not only funds, contacts, and collaborators but also an idea to make sense of the Web as a medium of self-expression. Building on his experience with Blogger, Williams considered blogging, with its associated notion of content creation through reverse chronological order, as part of "[his] DNA" (from an interview in Moggridge, 2010, p. 274).

Various factors altered plans for developing Odeo's program. The program did not generate the level of uptake that investors and producers expected. Moreover, Odeo's developers recall gradually losing interest in podcasting as the project unfolded. Programmer Evan Henshaw-Plath, Odeo's first employee and lead developer, states that the team lost interest when Odeo's offices relocated early in 2005 to San Francisco. "All of a sudden," he recalls, "no one had to commute, which meant that no one had any

abundance of spare time to listen to podcasting. So the interest declined quickly" (personal communication, August 23, 2011). Perhaps more significantly, in mid-2005, as Odeo worked on its podcasting program, Apple announced the release of an iTunes version with support for similar functions. This turn of events forced Odeo to look for alternative projects. The start-up thus began hackathons and brainstorming sessions, common activities in the Bay Area, as a way to look for new projects (Moggridge, 2010; Sagolla, 2009). Developers divided into small groups to discuss ideas. Based on the most promising proposals, teams worked to build software prototypes.

Among the proposals discussed were a program for recording and sharing video and a group voicemail service (Henshaw-Plath, 2011; Sagolla, 2009). An idea for an alternative project came from Jack Dorsey, one of Odeo's engineers. Dorsey envisioned a program for users to describe and report their activities and locations (which he referred to as "statuses") and share this information with groups of selected friends. He described how his idea had evolved for various years until he finally presented it at Odeo:

One night in July of [2000] I had an idea to make a more "live" LiveJournal. Real-time, up-to-date, from the road. Akin to updating your AIM [AOL Instant Messenger] status from wherever you are, and sharing it. For the next 5 years, I thought about this concept and tried to silently introduce it into my various projects. It slipped into my dispatch work. It slipped into my networks of medical devices. It slipped into an idea for a frictionless service market. It was everywhere I looked. (Dorsey, 2006b, para. 2)

Like Williams, Dorsey built on his previous work experience to envision new projects. He adopted the status concept from instant messaging (IM) communications and from the dynamics he had identified when he was developing Web applications for courier and taxi dispatch services in the early 2000s. Accordingly, he named this early program Stat.us. Through features such as contact (or "buddy") lists and tools to share one's availability, IM had become a common way of expressing moods and coordinates. Interested in the popularity of IM, developers such as Dorsey and Williams had reflected on how to extend the defining dynamics of this technology through new projects. In an interview with the *Los Angeles Times*, Dorsey explained,

[The idea] started with a fascination with . . . [entities] roaming about the metropolis, reporting where [they are] and what work [they have]. . . . But it's missing the public. . . . What really brought me to that conclusion was instant messenger. This aspect where you can just locate your buddy list and at a glance locate what your friends are up to, or what they say they're up to. I found the same parallels in dispatch. (From an interview in Sarno, 2009a, paras. 9-12)

Dorsey's program thus functioned as a remediation of IM, diary-writing applications, and dispatch services. Moreover, the software application would incorporate mobile short message services (SMS) and utilize this technology as a material support. By the mid-2000s, the use of SMS was gaining attention from operators and commentators in the United States. (The enthusiasm that devices such as the T-Mobile Sidekick triggered within certain groups of users in the country illustrates this phenomenon.) In this

context, Dorsey thought of SMS as the ideal technology for updating one's status and extending IM communication dynamics: It could allow users to exchange text messages sent through mobile phones to report their locations and activities.

Before settling on a name, developers jokingly referred to the program as FriendStalker (Henshaw-Plath, 2011; Sagolla, 2009). After consulting the dictionary for inspiration, Noah Glass suggested a new name for the program: Twitter. According to Dorsey,

We wanted a name that evoked what we did. . . . And we looked at what we were doing and when you received a tweet over SMS, your phone would buzz. It would jitter. It would twitch. And those were the early names, Jitter and Twitch. . . . Noah Glass took the word Twitch, and he went down . . . the Oxford English dictionary at the T-W's, and we found the word Twitter. (From an interview in Chow & Colgan, 2011, para. 3, 7)

The name evoked "a short inconsequential burst of information, chirps from birds" (Dorsey, 2011a). Developers adopted the short name Twtr, a five-letter word that could allow them to use the number formed by the digits that correspond to those letters on a telephone keypad (that is, 89887) as the code for reporting statuses through mobile phones.

Dorsey, Glass, Christopher "Biz" Stone (a Web developer who had worked with Evan Williams at Blogger after Google acquired it), and Florian Weber (a core contributor to the Ruby on Rails framework and who worked as a contractor for Odeo) began developing Twtr's prototype, while the rest of the company continued to work on Odeo's projects. The team turned to Ruby on Rails to program the application, because Weber was assigned to work on the project. A two-week deadline was set to finish the prototype. As a guide for organizing the development of the prototype, Dorsey wrote various potential scenarios (that he called "stories"), which described Twtr's virtual users in what he envisioned would be typical uses of the program. These stories portrayed users adding a new contact into the system (originally called a "friend"), updating statuses, reading the statuses of other friends (a practice that was referred to as "following"), inviting new users, and banning others from reading the user's statuses (Dorsey, 2011b). Users thus functioned as a representation that guided the conception of particular technological features. In the days that followed the brainstorming session, the team built a prototype that implemented Dorsey's stories and experimented with a SIM (subscriber identity module) card connected to a laptop. Weber recalls the work involved in this process as follows:

I would do the back-end development [and] all that sort of stuff. Jack [Dorsey] was mostly doing the front-end development, and then both of us were talking about how we want[ed] the product to work, what sort of things we thought were important or not. Biz [Stone] was still working at Odeo as well, so sometimes we had the luck of having him in there and helping us out with design work or certain product decisions. (F. Weber, personal communication, October 28, 2011)

In addition to finding the name and the domain name for the application, Glass, the team's manager, worked on the initial logo designs and implementing the SMS component. The prototype was

presented to the rest of the company on March 21, 2006. At this time, Dorsey (2006a) posted a message "inviting coworkers." Only workers at Odeo and close relatives and friends (primarily in the Bay Area) were given access to the program. This opening of the application to a select group of users had important implications, as will be explained later. Twitter gained enthusiastic early adopters within Odeo. Evan Williams recalls, "To get these messages was just fun! It was that human connection, fun, lightweight, the endorphin rush that drives a lot of the social activities on the Web and everywhere else, and it happened with this very simple mechanism" (from an interview in Moggridge, 2010, pp. 274–275). In this sense, Odeo's developers functioned as both producers *and* users with privileged access to the program's code.

Producing Twtr

Over the next weeks, a few programmers worked on scaling the prototype and developing it into a product for launch. As developers worked on scaling up the project, the range of remediation processes enacted through Twitter expanded (see Table 1). Building on their own professional experiences, backgrounds, and appropriation practices as users, developers at Odeo enacted Twitter's original idea in different ways. They subsequently built features to materialize these enactments. Bringing together work on remediation and multiplicity, Twitter's design and early development processes may be defined as multilayered intermediation—that is, as the enactment of multiple, coexisting layers of remediation. Start-up innovation dynamics provided the context in which new enactments took place. The developers suggest that the constant exchange of ideas that characterize start-up ventures was crucial in crystallizing this application in several ways. According to Henshaw-Plath,

Ideas aren't the product of a single person. The idea of Twitter came from the discussions that were happening and the ideas within Odeo. . . . Lots of people [had] ideas. We [had] lots of discussions about them. And then we built stuff. (Personal communication, August 23, 2011)

Odeo's programmers emphasized the notion of simplicity as a principle that guided their work. Williams, for example, had previously experimented with imposing constraints to achieve simplicity in the Blogger software. With Twitter, as Biz Stone put it, simplicity became a fundamental design paradigm: "[Simplicity has] turned into a basic philosophy for everything we do. So we ask, 'Are we getting too complicated?'" (from an interview in Glaser, 2007, para. 27). Henshaw-Plath recalls how simplicity operated as a "background" and a "context" for Twitter's early design: "[We were] very much interested in [answering]: 'What can you strip away? How can you remove the barriers to communication?'" (personal communication, August 23, 2011). Underlying this notion of simplicity was the view that limitations can function as a key stimulus for innovation. According to Dorsey, "We're fond of constraints that inspire creativity" (from an interview in Glaser, 2007, para. 46).

For some developers at Odeo, the application's reliance on SMS had precedents in technologies such as TXTMob, an alert system used by individuals to coordinate protests, particularly during the 2004 Republican National Convention. TXTMob allowed users to share messages with others through SMS during protests and thus coordinate their actions. For Blaine Cook and Evan Henshaw-Plath, two developers at Odeo with a background in activism, the use of SMS in protests provided a key model for

the type of uses that could be expected from the new application. For Cook, "We built [Twitter] with things like protests in mind. . . . [It] was explicitly about how to enable things like protest communications" (personal communication, October 22, 2011). Henshaw-Plath considered TXTMob "a model to be copied/learned from" in developing Twitter (Henshaw-Plath, 2008). In retrospect, he envisions activism as a driving force in Twitter's design:

We were building and demoing and prototyping activism platforms with SMS systems as the prototype for Twitter. . . . The whole company has always looked at and embraced the political uses of it and been very pleased with the fact that it was an active political platform. (Personal communication, August 23, 2011)

Other layers of remediation resulted from the experiences of developers acting as users. For example, developers identified some difficulties in utilizing SMS as the application's main messaging infrastructure. Because SMS users had to pay for each message sent and received, exchanging these messages was causing financial concerns. For Blaine Cook, a programmer from Vancouver who had recently moved to San Francisco and was still using a cell phone from Canada, receiving status updates via SMS was becoming expensive. Cook thus pushed for building a Web component as a supplement to the SMS infrastructure that could allow users to consult and manage their statuses online. (As the bills for using Twitter became higher, Odeo agreed to pay the texting bills of its employees.)

The possibility to follow friends through Twitter, contemplated in Dorsey's original stories, also tied the application to the rise of social network sites, a notion that gained traction at the time this tool was under development (boyd & Ellison, 2007). Thus, Twitter also could be envisioned as a remediation of this type of sites. This layer of remediation also resulted from previous work done at Odeo. According to Cook, "The 'Twitter-as-a-social-network' [was] pretty explicit; and 'Odeo-as-a-social-network' as well. You could sort of see what people were posting, and you could be friends with people on Odeo as well. Creating social connections was definitely present from day one" (personal communication, October 22, 2011).

These remediation layers coexisted in Twitter's early production. For developers, the tool extended practices such as blogging and diary writing; incorporated media technologies such as IM, the Web, and SMS; built on tools such as dispatch services, social network sites, and activism applications; and implemented design principles such as simplicity. Yet developers were also convinced that Twitter embodied something that could not be reduced to any single layer. In other words, when these layers were combined, developers argued that Twitter constituted "something new" (Dorsey, from an interview in Sarno, 2009b) and something that was difficult to describe. In retrospect, Dorsey claimed:

When I think of Twitter, I think of—it's really hard to define because we're still coming up with the vocabulary—but I think it's defined a new behavior that's very different than what we've seen before. [A] new medium. (Sarno, 2009b, para. 10)

Cook expressed a similar idea: "[Twitter] isn't [a] mobile thing. [It] isn't a Web thing. It's a communications medium . . . [and] platform. It's sort of above all of those things and it's independent of

them" (personal communication, October 22, 2011). Developers recall having multiple conversations about the best way to characterize Twitter throughout its development process.³

Table 1.
Layers of Remediation Enacted in Twitter's Creation, Production, Launch, and Early Use.

| Remediation | Enactment | Technology |
|---|--|---|
| LiveJournal, IM, dispatch services | Twitter as "a more 'live' LiveJournal. Real-time, up-to-date, from the road. Akin to updating your AIM" (Dorsey) | SMS as messaging infrastructure ("What up?") Use of 140 characters |
| Mobile applications for political activism (TXTMob) | Twitter as "an active political platform" (Henshaw-Plath) | SMS as messaging infrastructure |
| WWW | Twitter as an app for consulting and managing statuses online. Reducing the costs of using SMS | Web interface for managing Twitter ("Timeline") |
| Social network sites | Twitter as "creating social connections" (Cook) | Features to follow other users' activities and privilege their data ("Peeps") |
| Instant messaging | Twitter as an extension of forms of communication between programmers and geeks | IM access to Twitter |
| Blogs, short forms of publishing | Twitter as "blogging [without] all these features [and limiting] the size of the post" (Williams) | RSS, permalinks, timeline in reverse chronological order |
| Web-based applications | Twitter as a means for building new applications on the Web | API |
| Conversational media | Twitter as "a flow of communications relevant to users" (Cook) | @username, "in reply to" link, replies page |
| Articulating various layers of remediation: Twitter as a new medium | Twitter as "a new behavior that's very different than what we've seen before. A new medium" (Dorsey) | Twitter as a singular blend of features, technologies, and types of content |

³ In one of those conversations, Florian Weber recalls, the term *microblogging* was considered. Yet, he argues, the term was abandoned because some developers considered that the notion of *micro* would not hold against the term *nano* in the context of the recent release of the iPod nano.

Launching Twitter

In July 2006, Twtrr was publicly launched amid a restructuring process at Odeo.⁴ The application allowed early users to update their status and read the statuses of others by SMS or via the Web. The tool's early Web interface materialized the various remediation dynamics that shaped its conception and production processes. Thus, the interface presented three columns for enabling communication in specific ways. The first column was devoted to displaying updates from users on a public Web page or "timeline," enacting Twitter as a Web-based application. The second column, named "What Up?" invited users to "send updates from your cell phone or from the Web." Finally, the third column, named "Peeps," enacted Twitter as a social network site. It allowed users to "star the friends you really like and get their updates on your cell." New "friends" had to be invited and had to sign up by SMS.

Twtrr's launch was surrounded by some puzzlement. In news outlets, commentators often compared it to applications such as Dodgeball and Jaiku. In an early review, *TechCrunch's* Michael Arrington (2006) praised it by giving it "a thumbs up for innovation and good execution on a simple but viral idea" (para. 6). Yet he also raised concerns about privacy issues and the fact that Odeo was not a producer of SMS applications. In interviews for this study, Twitter's developers described the early adoption of the tool as "slow," "flat," and "without direction." In their perspective, one of the most significant challenges of this period was finding an appropriate way to define the application and convey its singularity. This can be interpreted as an expression of the difficulties involved in articulating Twitter's multilayered intermediation through a single, encompassing framework.

By the end of summer 2006, Twtrr was renamed Twitter. Exchanging SMS messages in standardized ways, however, posed several technical challenges. Long status updates could be spread over multiple SMS messages that arrived in different order. Weber explains:

Initially . . . people could send longer updates [that] would just spread out over multiple SMSs. That caused all kinds of headaches. In the U.S. [SMS] was still not reliable so you [would] get the second [message] first, and then the first one. (Personal communication, October 28, 2011)

In this context, developers adopted a "creative constraint" to define the maximum number of characters that could be used to share a status. SMS infrastructure worked with a unique 160, seven-bit characters standard. Because sharing status updates would require including the name of the user who wrote them

⁴ Several employees at Odeo were laid off in the spring and summer of 2006. In September 2006, Williams bought Odeo's shares from investors. He noted that in the shift from Odeo to Twitter, the company had deviated from the direction and technologies that investors had originally envisioned. Williams named the new company Obvious LLC. See Carlson (2011) for a journalistic description of the controversy surrounding this turn of events.

(up to 18 characters), a colon, and a space before displaying each message (one character for each), developers settled on 140 characters.⁵

In the following months, the layers of remediation enacted by Twitter continued to expand. Developers implemented new ways, in addition to SMS and the Web, to access and use the application. Once again, they built some of these features as responses to emerging problems they faced as users. For example, Florian Weber, who had to return to Germany while the team worked on the prototype, experienced problems receiving messages outside the United States. As a solution, Weber thought about implementing an access to Twitter that did not involve the use of SMS. He recalls doing what he describes as a “quick hack” that allowed Twitter’s developers to exchange messages through IM. Some developers then began to exchange messages this way. Because they noticed the potential value of this practice for users, they added an IM access to Twitter as a feature in October 2006. In this sense, developers exploited their experiences as users and their privileged access to the program’s code. During the same month, they also implemented RSS and permalinks for timelines—two key affordances of blogging.

Innovation dynamics that characterize Silicon Valley played an important role in the development of Twitter. This context enabled the formation of a web of interactions between groups of developers (both inside and outside Twitter), users, and geeks who shared some of the same values and cultural ethos. It created the grounds for exchanges between developers (functioning as privileged users) and users (operating as developers). Important expressions of this cultural context were feedback loops established between Twitter’s engineers and other developers. In particular, the release in September 2006 of an application programming interface (API) embodied an invitation to other developers and users to participate in shaping Twitter. In the fall of 2006, programmers outside the company released new applications to use Twitter, such as Mo.ist, Celly, Twittermap, and Twitter for iChat. According to developers, these applications significantly helped Twitter to gain new users.

Using Twitter

How users appropriated Twitter is important for understanding its development. As noted, early users were not disconnected from Twitter’s production context. Some of them were influential figures in the Bay Area, skilled programmers and engineers with years of professional experience, or geeks who shared a fascination for Web technologies and services. An early developer of the application recalls:

[Twitter’s] initial community of users was centered around San Francisco, centered around friends of Ev’s [Williams] and the other people working at Obvious [Odeo’s new name]. . . . [Twitter] had roots in this very vocal and not necessarily influential community, but this community that has this ability to kind of manufacture its own influence. (Interviewee, personal communication)

⁵ Sagolla (2009) suggests that Odeo’s desire to reduce texting bills also motivated the adoption of this standard.

Developers and early users typically encountered each other in person during activities such as social events, meetings, and conferences. Some users were also invited to stop by Twitter's offices to work on particular issues and exchange ideas. (Over the next years, these exchanges would also take place in events such as FOO Camp.)

In addition to the new applications developed for Twitter through its API, users shaped the application through appropriation practices that departed from Twitter's original purposes. For example, in the months after its launch, besides reporting their coordinates, users began using Twitter to sustain conversations with one another and aggregate news. These user enactments can be interpreted through the lens of remediation theories. For example, journalist Dan Gillmor, who created a Twitter account early in 2007, appropriated Twitter to extend writing practices that dated back to the late 1990s, particularly blogging. He explains:

A lot of my early blogging was a link, a short quote, and then my further analysis. [It] was a way of saying to my readers, "Hey, you should take a look at this!" [With Twitter] I reestablish[ed] that habit. (Personal communication, July 19, 2011)

In this view, Twitter remediated blogging through the lens of its simplicity and creative constraints. Evan Williams captured the essence of this enactment when he defined Twitter as "tak[ing] blogging, tak[ing] out all these features and limit[ing] the size of the post and that will be a whole thing" (from an interview in Moggridge, 2010, p. 278).

Furthermore, users enacted Twitter by remediating media used to interact with others rather than seeing it as a way to only share statuses. In late 2006, they began incorporating the @ symbol as a way to reply to one another (Crosby, 2006). The use of the @ symbol is not accidental; it is an expression of the common values and cultural ethos shared by both Twitter's developers and users. The @ symbol is a key feature of Internet Relay Chat (IRC); users commonly employ it as a reply feature. Created in the late 1980s, IRC had experienced a revival within circles of hackers and software developers (Coleman, 2013). In this context, the use of the @ symbol resonated with developers at Twitter who had appropriated this technology as a back channel in the context of their work, conferences, and other activities. This enactment of Twitter led to iterative feedback loops between users and developers that significantly shaped the application's development (see Figure 1). As a response to this practice, Twitter's developers created features that helped users appropriate it as a conversational medium. As Biz Stone (2007a) explained on Twitter's official blog, "We started supporting this behavior by doing things like creating the *in reply to* link . . . and linking the @username to a profile" (para. 1, emphasis in original). Conversations through Twitter proliferated after these features were introduced.

As a feedback loop, interactions between users and developers had consequences for the enactment of Twitter as a conversational medium. As developers noticed how users enacted the application, they reflected on how to help users sustain what they defined as "relevant conversations," as opposed to any other type of conversation. This process led developers to distinguish between data that pertained to the realm of relevant conversations and those that instead "polluted" user exchanges. Blaine Cook, Twitter's chief architect at the time and the person who implemented this change, explains:

There [were] too many side conversations and it kind of pollute[d] the screen. It [was] very distracting. [We] changed it so [users] wouldn't see those messages anymore and [could] have a flow of communications that [were] relevant to [them]. (Personal communication, October 22, 2011)

Developers thus implemented a feature that filtered the type of conversations that were displayed on users' profiles. Although at first a person's followers on Twitter could see every conversation held by that person, developers changed this feature to display only conversations between people followed by the user. Whereas the latter were considered relevant conversations and therefore kept in the user's timeline, the former were defined as "non-relevant" and hidden from users.

Twitter's developers also implemented new features, such as the "replies page," launched in May 2007, to allow users to keep a record of these relevant conversations. Alex Payne, a programmer who joined Twitter in January 2007 and managed its API, recalls:

We were keeping track of users replying to other users, but we hadn't exposed that in Twitter's interface for a number of months. One afternoon, [we] said, "We've got the data in here. Why don't we just put a tab in the interface where you can see everyone who's replying to you?" It took five minutes to build. That's something that the users had started doing on their own. We just kind of picked up on it and made it easier for them to do. (Personal communication, July 13, 2011)

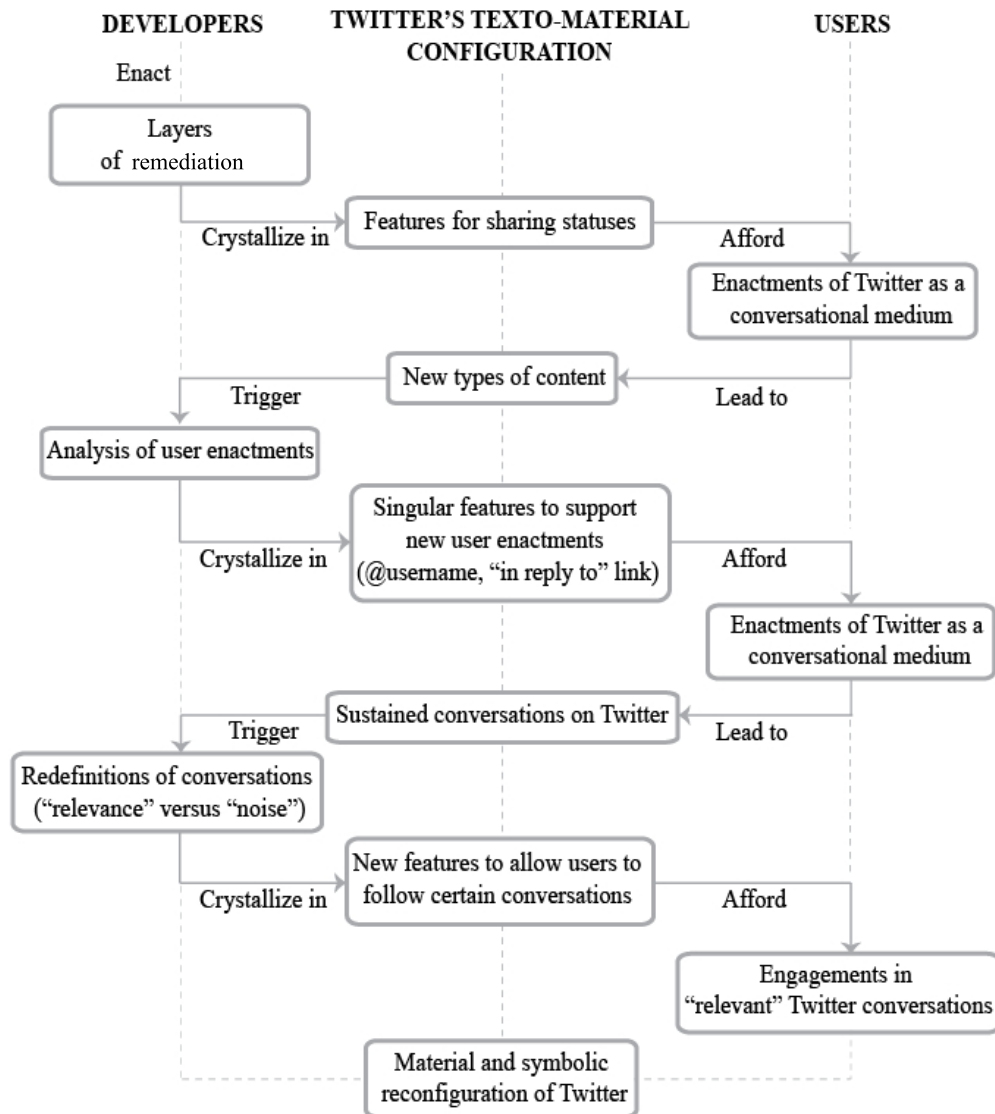


Figure 1. Feedback loops between Twitter’s developers and early users.

Through similar iterative feedback loops, Twitter’s developers adopted user practices and incorporated them into the application over the next months. These included the use of the # symbol (or “hashtag”) to categorize content and the reference to posts as “tweets” (rather than “status updates”).⁶ In

⁶ “In the spirit of simplification,” Biz Stone (2007b) explained, the term *friend* was also abandoned, and a unidirectional “follower” model was adopted in July 2007.

August 2007, Chris Messina, a Web developer and open source advocate, began using the # symbol to improve “contextualization, content filtering and exploratory serendipity within the Twittosphere” (Messina, 2007, para. 1). Messina explicitly interpreted this practice as a remediation of IRC. He explained: “It occurred to me that IRC presents a proven model for these needs with its foundation on channels, and so that’s what I’m generally going to call them” (Messina, 2007, para. 9). Like the @ symbol, the use of hashtags illustrates the centrality of certain early users in shaping the tool. As an experienced software developer in Silicon Valley, Messina was aptly situated to participate, through his appropriation practices and exchanges with Twitter’s producers, in shaping this application.

Primarily because of aesthetic concerns, many Twitter’s developers resisted the use of hashtags. Yet they incorporated the feature when the company bought a search engine that had adopted this practice. Payne explains:

[Some developers] pushed back against us formally acknowledging hashtags for as long as [they] could. But, eventually [Twitter] bought a company [Summize] that was indexing tweets and providing a search engine for those tweets [that] had picked up on the hashtag thing. . . . So when we started integrating those two products, we sort of had to acknowledge [them]. If our search engine thinks that hashtags are a legitimate concept, then the rest of the product probably should as well. (A. Payne, personal communication, July 13, 2011)

In this sense, the stabilization of this feature involved feedback loops with other developers.

Certain events in the new media development field, particularly the South by Southwest (SXSW) conference, were key in Twitter’s development. In March 2007, Williams and some members of the team attended SXSW, a technology conference where Williams enjoyed a privileged symbolic position, to demonstrate Twitter. SXSW was instrumental in the tool’s development for two reasons. First, it allowed developers to recruit new geek users who later contributed to shape Twitter through their practices and expertise. Second, it helped the application to gain more prominence in public culture. When it received the Web Award in the blog category at SXSW, Twitter began to receive more attention from the mainstream media.

In sum, iterative exchanges between developers and certain users resulted in the material and symbolic transformation of Twitter. Materially, these feedback loops led to specific features that made it easier for users to sustain conversations and filter those conversations in particular ways. Symbolically, these interactions redefined Twitter. In 2006, when the application was launched, its website defined Twitter as a “global community of friends and strangers answering one simple question: What are you doing?” (Twitter, 2006). However, by 2007, when the use of Twitter as a conversational tool had stabilized, developers modified this description to accommodate new user enactments. They redefined it as “a service for friends, family, and co-workers to *communicate* and *stay connected* through the *exchange* of quick, frequent answers to one simple question: What are you doing?” (Twitter, 2007, emphasis added). In this way, Twitter became more than a program for sharing coordinates.

Concluding Remarks

This article examined Twitter's invention and early development processes by deploying an iterative approach that accounted for the role of both developers and users, how these actors enacted Twitter, and how their enactments and interactions crystallized into particular technological features over time. To conclude, I elaborate on how this approach can inform our understanding of new media development and broaden the analytical reach of extant theoretical frameworks.

By focusing on feedback loops between developers and users (iteration as an action), this article revealed the role of both groups of actors in Twitter's creation. An investigation of the work of developers was crucial in making visible the dynamics that guided Twitter's conception and production processes. It brought to light the variety of experiences and expectations that shaped Twitter's creation and that crystallized in specific remediation dynamics. Yet a history of Twitter would be incomplete without a careful consideration of users. By departing from Twitter's prescribed uses in creative ways and developing novel tools to expand its range of functions, early users played a crucial role in shaping the application. In this sense, technology producers do not predefine the shape of media technologies once and for all during design activities by remediating previous content configurations (as suggested by scholarship on remediation). Instead, users actively enact and shape remediation through particular practices. Thus, an account of the feedback loops between developers and users was indispensable for explaining how Twitter was reconceived, both materially and symbolically, as a conversational medium.

The analysis of how these feedback loops evolved over time (iteration as process) demonstrated how developers and users exchanged roles in various ways. On the one hand, developers relied on their own user experiences of previous media technologies to imagine Twitter's purpose(s). They also appropriated Twitter during its early phases of development and identified problems in its use. Building on their own appropriation practices and taking advantage of their privileged access to the program's code, they introduced novel features to solve the problems they identified *as users*. On the other hand, users acted *as developers* in various ways. When programmers first imagined the set of potential appropriations of Twitter, users operated as idealized constructions that guided the tool's design. Moreover, when programmers and geeks with experience in Web development were given access to Twitter, they shaped the application by building new applications for it and by employing it in ways different than originally anticipated. Over time, these practices led to features that were incorporated into the tool.

The focus on how Twitter was variously enacted (iteration as product) allowed tracing the multiple pathways that shaped its configuration through both production and use activities. For its developers, Twitter crystallized a variety of different remediation processes. Dorsey envisioned it as a new instantiation of an online diary-writing program, instant messaging, and SMS communication. Williams invoked his previous experience in software development when he defined Twitter as a constrained version of blogging. Users linked Twitter to the history of conversational media and news aggregation devices. Both developers and users built specific features to materialize these different remediation layers. To account for this multiplicity of enactments, I posited the term *multilayered intermediation*. The definition of Twitter as a new medium is, precisely, an attempt to reconcile the multiplicity of remediation dynamics enacted during its production and use. This finding is significant in that it partly explains how

Twitter acquired specific material configurations.

It is important to stress the significance of the particular spatial and temporal context in which this case unfolded. As scholars have noted, culture and place matter for both the production and appropriation of media technologies (Balsamo, 2011; Oudshoorn, 2011). How developers and users enacted Twitter was a partial product of their particular cultural experiences. Furthermore, the values and dynamics that characterize Silicon Valley were crucial in bringing Twitter's developers and users together in particular ways and in enabling a network of exchanges between them. To be sure, there are contexts and situations where the boundaries between producers and users are more strongly protected and iterative dynamics less likely to unfold. In Twitter's case, this spatial and temporal context made it possible for certain programmers and geeks to appropriate the tool and thus perform the role of users. In turn, Twitter's producers envisioned these programmers as situated and legitimate actors who could contribute to the tool's development through their use practices and expertise. This context also allowed developers to incorporate their own user experiences as inputs in production.

This article focused exclusively on Twitter's early development. Yet, by identifying a series of iterative dynamics, this approach can inform an analysis of Twitter's subsequent evolution. In this sense, considering how new types of users and usages have emerged and stabilized, how Twitter's development team has changed, how developers have worked to turn Twitter into a profitable venture, what new types of feedback loops have emerged between increasingly large groups of developers and users, and what types of identities Twitter has enacted over a longer time could open new avenues for research (cf. van Dijck, 2011).

To implement this iterative approach, this article integrated various theoretical frameworks. By so doing, this study expanded the heuristic reach of these frameworks. On the one hand, theories on remediation were brought to bear on work on the user-technology relationship. In this sense, this analysis extended the study of remediation dynamics by showing that media technologies are open to a multiplicity of enactments throughout production *and* use activities. To account for remediation mechanisms, scholars have privileged the study of the production and design of media technologies (Bolter & Grusin, 1999; Hayles, 2005). Yet this article demonstrated that remediation must also be examined when media technologies are used. By discussing the examples of the @ symbol and the hashtag, the study pointed to the need to investigate how remediation also provides users with important symbolic and material elements with which to enact and make sense of emerging media technologies. From this perspective, remediation dynamics constitute a key bridge between the study of the production and the use of media.

On the other hand, theories on remediation were rethought in light of work on user agency. Against the backdrop of Bolter and Grusin's (1999) notion that "a medium is that which remediates" (p. 65), Twitter's creation can be analyzed as the development of a new medium. Yet the study of Twitter's invention shows that remediation is not enacted through a singular and unique dynamic oriented toward either immediacy or hypermediacy. Instead, as a medium under development, Twitter enacted various layers of remediation through software design dynamics and user practices (see Table 1). In this sense, the notion of enactment helps to broaden our understanding of remediation processes.

Furthermore, work on the agency of users has emphasized how media technologies acquire different configurations as they are enacted through use activities. Orlikowski (2000) thus distinguishes between technologies as artifacts (i.e., assemblages of material and symbolic properties) and technologies-in-practice (i.e., the specific ways in which users enact these sociomaterial assemblages in particular ways). Yet Orlikowski (2000, p. 414) reserves the notion of enactment to conceptualize user practices and characterizes media technologies instead by enumerating some of their properties. As a supplement, this analysis revealed that the enactment of technology does not begin in and is not exclusive to use activities. In other words, technologies do not become technologies-as-practice exclusively when they are used; the multiple ways in which they are enacted during production and development activities are also critical for their understanding as technologies-in-practice. Therefore, a consideration of how media technologies are variously enacted must be extended to production processes and to the interactions between use, production, and intermediary activities.

In summary, understanding how media technologies emerge and develop in dynamic ways requires considering how actors such as developers and users engage in various practices through which they enact media technologies, how these actors interact, and how these enactments and feedback loops crystallize into specific artifacts over time. At stake in the study of these processes is not only an understanding of how media technologies such as Twitter can be aptly defined but the provision of foundations for rethinking how they emerge, change, and evolve over time.

References

- Arrington, M. (2006, July 15). Odeo releases Twtr. *TechCrunch*. Retrieved from <http://techcrunch.com/2006/07/15/is-twtr-interesting>
- Balsamo, A. M. (2011). *Designing culture: The technological imagination at work*. Durham, NC: Duke University Press.
- Boczkowski, P. J. (2010). *News at work: Imitation in an age of information abundance*. Chicago, IL: University of Chicago Press.
- Boczkowski, P. J., & Siles, I. (In press). Steps toward cosmopolitanism in the study of media technologies: Integrating scholarship on production, consumption, materiality, and content. In T. Gillespie, P. J. Boczkowski, & K. Foot (Eds.), *Media technologies: Essays on communication, materiality and society* (pp. 53–75). Cambridge, MA: MIT Press.
- Bolter, J. D., & Gromala, D. (2003). *Windows and mirrors: Interaction design, digital art, and the myth of transparency*. Cambridge, MA: MIT Press.
- Bolter, J. D., & Grusin, R. (1999). *Remediation*. Cambridge, MA: MIT Press.
- boyd, d., & Ellison, N. B. (2007). Social network sites: Definition, history, and scholarship. *Journal of Computer-Mediated Communication*, 13(1), 210–230.
- Carlson, N. (2011, April 13). An interview with Twitter's forgotten founder, Noah Glass. *Business Insider*. Retrieved from <http://www.businessinsider.com/twitter-cofounder-noah-glass-2011-4?op=1>
- Chow, L., & Colgan, J. (2011, July 18). How Twitter was nearly called Twitch. *WNYC*. Retrieved from <http://www.wnyc.org/articles/wnyc-news/2011/jul/18/twitter-co-founder-jack-dorsey-how-his-company-was-nearly-called-twitch>
- Coleman, E. G. (2013). *Coding freedom: The ethics and aesthetics of hacking*. Princeton, NJ: Princeton University Press.
- Corbin, J. M., & Strauss, A. L. (2008). *Basics of qualitative research: Techniques and procedures for developing grounded theory* (3rd ed.). Thousand Oaks, CA: SAGE Publications.
- Crosby, N. (2006, November 23). *Twitter*. Retrieved from <https://twitter.com/#!/NeilCrosby/status/139513>
- Denzin, N. K. (1978). *The research act: A theoretical introduction to sociological methods* (2d ed.). New York, NY: McGraw-Hill.

- Dorsey, J. (2006a, March 21). *Twitter*. Retrieved from <https://twitter.com/#!/jack/status/29>
- Dorsey, J. (2006b). twttr sketch. *Flickr.com*. Retrieved from <http://www.flickr.com/photos/jackdorsey/182613360>
- Dorsey, J. (2011a, March 13). *Twitter*. Retrieved from <https://twitter.com/#!/jack/status/47061540951687169>
- Dorsey, J. (2011b). twttr's stories. *Jacks.tumblr.com*. Retrieved from <http://jacks.tumblr.com/post/3842942169/twttr-stories>
- Eglash, R. (2004). Appropriating technology: An introduction. In R. Eglash, J. L. Croissant, G. Di Chiro, & R. Fouché (Eds.), *Appropriating technology: Vernacular science and social power* (pp. vii–xxi). Minneapolis: University of Minnesota Press.
- Fischer, C. S. (1992). *America calling: A social history of the telephone to 1940*. Berkeley: University of California Press.
- Foot, K., & Schneider, S. (2010). Object-oriented Web historiography. In N. Brügger (Ed.), *Web history* (pp. 61–79). New York, NY: Peter Lang.
- Glaser, M. (2007, May 17). Twitter founders thrive on micro-blogging constraints. *PBS*. Retrieved from <http://www.pbs.org/mediashift/2007/05/twitter-founders-thrive-on-micro-blogging-constraints137.html>
- Hayles, N. K. (2002). *Writing machines*. Cambridge, MA: MIT Press.
- Hayles, N. K. (2005). *My mother was a computer: Digital subjects and literary texts*. Chicago, IL: University of Chicago Press.
- Hayles, N. K. (2007). Intermediation: The pursuit of a vision. *New Literary History*, 38(1), 99–125.
- Henshaw-Plath, E. (2008, March 31). TXTMob gets subpoenaed. *Anarchogeek*. Retrieved from <http://anarchogeek.com/?s=TXtmob>
- Henshaw-Plath, E. (2011). La historia secreta de Twitter & el modelo de los lean startups [The secret history of Twitter & the model of lean startups]. *Slideshare*. Retrieved from <http://www.slideshare.net/rabble/la-historia-secreta-de-twitter-el-modelo-de-los-lean-startups>
- Hyysalo, S. (2010). *Health technology development and use: From practice bound imagination to evolving impacts*. London, UK: Routledge.

- Law, J. (2002). *Aircraft stories: Decentering the object in technoscience*. Durham, NC: Duke University Press.
- Law, J. (2008). On sociology and STS. *Sociological Review*, 56(4), 623–649. Retrieved from <http://factoryjoe.com/blog/2007/08/25/groups-for-twitter-or-a-proposal-for-twitter-tag-channels>
- Messina, C. (2007, August 25). Groups for Twitter; or a proposal for Twitter tag channels. *FactoryJoe*. Retrieved from <http://factoryjoe.com/blog/2007/08/25/groups-for-twitter-or-a-proposal-for-twitter-tag-channels>
- Millerand, F., & Baker, K. S. (2010). Who are the users? Who are the developers? Webs of users and developers in the development process of a technical standard. *Information Systems Journal*, 20(2), 137–161.
- Moggridge, B. (2010). *Designing media*. Cambridge, MA: MIT Press.
- Mol, A. (2002). *The body multiple: Ontology in medical practice*. Durham, NC: Duke University Press.
- Orlikowski, W. J. (2000). Using technology and constituting structures: A practice lens for studying technology in organizations. *Organization Science*, 11(4), 404–428.
- Oudshoorn, N. (2011). *Telecare technologies and the transformation of healthcare*. New York, NY: Palgrave Macmillan.
- Oudshoorn, N., & Pinch, T. (2003). Introduction. In N. Oudshoorn & T. Pinch (Eds.), *How users matter: The co-construction of users and technology* (pp. 1–25). Cambridge, MA: MIT Press.
- Ross, P. (2012). Were producers and audiences ever separate? Conceptualizing media production as social situation. *Television & New Media*. OnlineFirst version. doi:10.1177/1527476412454686
- Sagolla, D. (2009). *140 characters: A style guide for the short form*. Hoboken, NJ: Wiley.
- Sarno, D. (2009a, February 18). Twitter creator Jack Dorsey illuminates the site's founding document. Part I. *Los Angeles Times*. Retrieved from <http://latimesblogs.latimes.com/technology/2009/02/twitter-creator.html>
- Sarno, D. (2009b, February 19). Jack Dorsey on the Twitter ecosystem, journalism and how to reduce reply spam. Part II. *Los Angeles Times*. Retrieved from <http://latimesblogs.latimes.com/technology/2009/02/jack-dorsey-on.html>
- Spradley, J. P. (1979). *The ethnographic interview*. New York, NY: Holt, Rinehart and Winston.

- Stone, B. (2007a, May 29). Are you twittering @ me? *Twitter blog*. Retrieved from http://blog.twitter.com/2007_05_01_archive.html
- Stone, B. (2007b, July 19). Friends, followers, and notifications. *Twitter blog*. Retrieved from <http://blog.twitter.com/2007/07/friends-followers-and-notifications.html>
- Twitter. (2006). Retrieved from <http://web.archive.org/web/20061109073453/http://twitter.com>
- Twitter. (2007). What is Twitter? Retrieved from <http://web.archive.org/web/20071107192258/http://twitter.com>
- van Dijck, J. (2011). Tracing Twitter: The rise of a microblogging platform. *International Journal of Media and Cultural Politics*, 7(3), 333–348.
- Wajcman, J., & Jones, P. K. (2012). Border communication: Media sociology and STS. *Media, Culture & Society*, 34(6), 673–690.
- Williams, R., Stewart, J., & Slack, R. (2005). *Social learning in technological innovation: Experimenting with information and communication technologies*. Cheltenham, UK: Edward Elgar.