It Is About Timing: Network Prestige in Asynchronous Online Discussions

Bodong Chen, University of Minnesota

Tianhui Huang, Yunnan University

Author Note

(in press). Journal of Computer Assisted Learning. DOI: 10.1111/jcal.12355

Abstract

Asynchronous online discussions are broadly used to support social learning. This paper reports on an undergraduate class's online discussion activities over one semester. Applying Social Network Analysis, this study revealed a participation gap among students reflected by their varied levels of network prestige. The low-prestige group initiated equivalent volumes of interactions but were less reciprocated. In-depth analysis found the high-prestige group also advantageous in other network measures such as closeness centrality and eigenvector centrality, as well as the strength, persistence, and reciprocity of their ties. To probe potential explanations of the revealed gap, we further contrasted post content and posting behaviors between two groups. Results did not identify any significant differences in post content but found low-prestige students' participation less timely and more temporally compressed. This paper calls for attention to the participation gap in online discussions, micro-level temporal patterns of student activities, and practical means to scaffold student participation in asynchronous online discussions.

Keywords: asynchronous online discussions; online learning; social network analysis; temporal analysis; computer-mediated communication

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1. Introduction

Asynchronous online discussions have been broadly used to support social interaction in various contexts of learning that follow the social constructivist paradigm. In online and blended classes, students are often instructed to post reflections, share ideas, and comment on each other's posts in online forums (Chan, Hew, & Cheung, 2009). In programming classes, students embark on sophisticated information-seeking journeys on social question and answer (Q&A) sites (e.g., Stack Overflow) to achieve learning goals (Lu, Sharon, & Hsiao, 2016). In massive open online courses, discussion forums provide the main mechanism for learners to forge connections with peers from around the world (Rosé & Ferschke, 2016). In less structured learning settings, social media and online discussion spaces such as Reddit play critical roles in connecting lifelong learners with information and learning partners (Greenhow & Robelia, 2009; Haythornthwaite et al., 2018). Despite technological differences of these asynchronous online discussion spaces, they share a same purpose of facilitating social interaction among learners.

Social interaction in asynchronous online discussions has attracted substantial research attention, leading to empirical findings that have theoretical, pedagogical, and technological implications. Prior research of asynchronous online discussions has studied the instructor's role (Mazzolini & Maddison, 2007), peer facilitation strategies (Chan, Hew, & Cheung, 2009), technological design of discussion environments (Guzdial & Turns, 2000; Scardamalia & Bereiter, 2003), interaction patterns (Dringus & Ellis, 2010; Jo, Park, & Lee, 2017; Wise & Chiu, 2011), and community structures (So, 2009; Wise & Cui, 2018), leading to various strategies for facilitating effective asynchronous online discussions.

Despite substantial work in this area, an enduring problem facing asynchronous online discussions is a participation gap among learners. The participation gap is not only reflected by different rates of participation by learners, different levels of conceptual engagement, and different circles of interacting peers (Dawson, 2010; Vaquero & Cebrian, 2013). More profoundly, the participation gap engenders varied social configurations that can facilitate or undermine learner performance. To support success of all learners in social constructivist learning environments, more research is needed to understand the participation gap and probe its possible causes.

With this recognition, the present paper attempts to reveal, characterize, and explain network *prestige* in an asynchronous online discussion space of an undergraduate class. In a directed social network, prestige reflects an actor's success in attracting peer attention in relation to the actor's activity level. By focusing on the sociological construct of prestige, this study seeks to advance our understanding of social dynamics in online discussions and to suggest practical means to mitigate the participate gap. Below, we first survey pertinent education and sociology literature. Then we introduce the research context and study design. After presenting and discussing main findings, we discuss scholarly significance of the study, practical implications, and future directions.

2. Literature Review

2.1 Social Participation in Online Discussions

Learning is inherently social, no matter whether it is about language development of children (Carey & Bartlett, 1978), science learning in K-12 classrooms (Chin & Osborne, 2010), or the development of the newest surfing tricks by avid hobbyists (Hagel, Brown, & Davison, 2012). Over the past decades, this recognition has motivated an expansion of the conceptualization of learning from *acquiring* knowledge as entities, to include *participating* in social activities that are conducive to knowing (Sfard, 1998). Social participation is essential in formal classrooms as well as in emerging contexts of learning, where learning happens through legitimate peripheral participation, game plays, new media practices, and artifact fabrication (Ito et al., 2013; Jenkins, 2006).

The recognized importance of social participation for learning has triggered widespread efforts to foster it, especially through the design and use of digital environments. Back in the 1980s, the Computer Supported Intentional Learning Environment (CSILE) was developed to support group learning mediated by conceptual artifacts stored in a virtual discussion space (Scardamalia, Bereiter, & Lamon, 1994). The Web 2.0 movement has greatly expanded the online space for social encounters, leading educators to explore social affordances on various social media platforms (Greenhow & Robelia, 2009; Lewis, Pea, & Rosen, 2010). Gaming environments and virtual worlds such as Civilization and Minecraft are also harnessed to support rich modalities of social learning (e.g., Dezuanni, O'Mara, & Beavis, 2015).

Among various digital tools, asynchronous online discussions, one of the most popular computer-mediated communication (CMC) technologies, are widely applied to supporting social participation in education. Since its inception, CMC has been recognized as an important learning resource that can support learner communication and shape the formation of learning cultures (McAteer, Tolmie, Duffy, & Corbett, 1997). In particular, asynchronous online discussions are often used to facilitate idea sharing, resolve student confusion, coordinate cognitive actions, support negotiation, scaffold group knowledge building, and maintain social bonds within a learner community (Fields et al., 2016; Resnick, Säljö, Pontecorvo, & Burge, 1997; Stahl, 2006). In successful cases, online discussions can engender positive student experiences by enabling discussion that is active, interactive, constructive, and hereby conducive to learning (Chi & Menekse, 2015).

Empirical studies of asynchronous online discussions have broadly covered interaction patterns, pedagogical practices, potential benefits, and implementation challenges. For instance, Hewitt (2005) studied patterns in online discussions and found the learner's "single-pass discourse practices" contributing to premature abandonment of discussion topics. While online forums provide affordances for learner communication, their thread-based design often leads to repetition and duplication in different threads (Thomas, 2000). Many pedagogical strategies have been proposed to mitigate these challenges, such as engaging students to take different roles (Wise & Chiu, 2011), incorporating different questioning strategies (Wang, 2005), and scaffolding students' socio-metacognitive skills (Borge & White, 2016). Studies probing the

efficacy of online discussions found participation intensity predictive of learning performance (Jo et al., 2017; Joksimović, Gašević, Kovanović, Riecke, & Hatala, 2015; Russo & Koesten, 2005), pointing towards the potential benefits of scaffolding learner participation in online discussions.

2.2 The Participation Gap in Online Discussions

Despite benefits of online discussions reported in the literature, social participation in online discussions often varies among learners. For example, Vaquero and Cebrian (2013) report a “rich club” phenomenon that encourages social interactions among high-performing students while posing barriers to participation against low-performing students who could not effectively blend in. Similar findings are independently reported elsewhere (Dawson, 2010), calling for more research on the *participation gap* in online discussion environments. Admittedly, these observations of the participation gap may have unique sociological determinants, given elite players, celebrities, or “VIP-clubs” are commonly observed in various social contexts (e.g., Masuda & Konno, 2006). Notwithstanding, understanding the nature and mechanism of the participation gap in online discussions is imperative for both research and practice.

We conceptualize the participation gap in online discussions as a complex, dynamic phenomenon that is shaped by behavioral, cognitive, social, and emotional characteristics of participants, together with social structures, rules, norms, and cultures forming within the discussion environment. The shifting participation gap can be characterized using sociological terms and network metrics. For instance, the participation gap in online classes can be characterized as a *rich-club phenomenon* (Vaquero & Cebrian, 2013), a sociological term widely applied and jointly developed in fields such as computer networks (Zhou & Mondragon, 2004), sports management (Masuda & Konno, 2006), and neuroscience (Daianu et al., 2014; van den Heuvel & Sporns, 2011). At the individual level, another sociological term *prominence* (Burt, 2000) can be used to characterize an actor’s favorable position in a network and advantages that come with such positions. According to Knoke and Burt (1983), “An actor is prominent to the extent that he is involved in relationships that make him an especially visible member of a social system” (p. 198). Network prominence is further categorized into network *centrality* and *prestige*—respectively for undirected/symmetric and directed/asymmetric networks. The concept of *centrality* is concerned with the extent to which an actor is involved in symmetric relationships, whereas *prestige* captures the directionality embedded in prominence (Torfason & Kitts, 2011). In particular, high-prestige actors can attract more incoming connections while low-prestige actors initiate outgoing connections but are not necessarily reciprocated (Knoke & Burt, 1983; Torfason & Kitts, 2011). Varied levels of prestige contribute to the emergence of self-esteem and social capital of individuals (Ellison, Steinfield, & Lampe, 2007), as well as social stratification of larger social systems (Wegener, 1992). Related to prestige, other sociological constructs, such as *preferential attachment* (Barabasi & Albert, 1999) and the *Matthew effect* (Perc, 2014), are also observed in real-world scholarly communication and computer networks. In empirical studies, the prestige concept is operationalized using network metrics such as *indegree centrality* (Russo & Koesten, 2005) and *eigenvector centrality* (Bonacich, 1987;

Bergstrom, 2007). For the investigation of online discussions, the multifaceted concept of prestige and its related metrics can help us move beyond basic counts of discussion behaviors to capture the interactional and asymmetric aspects of the participation gap (e.g., Cho, Stefanone, & Gay, 2002).

2.3 Factors Related to Participation in Online Discussions

Previous studies have reported various factors contributing to different levels of learner participation in online discussions (Nandi et al., 2012; Ouyang & Scharber, 2017). Activity design and instructor presence matter, as researchers find them affecting online discourse in a class (Dennen, 2005). Facilitation techniques also matter because the *Resolving* and *Summarizing* facilitation techniques may lead to early thread termination and the *Questioning* technique is needed to enhance thread continuity (Chan, Hew, & Cheung, 2009). Technological features of forums also play important roles, as they help learners understand how, what, and where to contribute (Guzdial & Turns, 2000; Warren & Rada, 1998). Grounded in an informed synthesis of the literature, Zingaro and Oztok (2012) constructed a statistical model that predicts the likelihood a post would receive a reply; their model is based on six quantitative predictors: the note's posting date, written by active or inactive participant, ease of reading, word count, written by student or instructor, and containing a question. They found notes that were longer, written early in the week, and containing at least one question were more likely to be replied, while readability did not make a difference in their study context. Overall, learner participation in online discussions is multifaceted and has been related to many factors.

2.4 Methodological Approaches to Investigating Participation in Online Discussions

Studies of learner participation in online discussions have benefited from multiple methodologies (Jo et al., 2017). A wide range of methodological approaches, such as Social Network Analysis, Content Analysis, and Regression Analysis, have been applied to studying student participation and its contributing factors. For instance, both social network visualizations and indices are widely adopted to depict and/or to measure social participation (Chen, Chang, Ouyang, & Zhou, 2018; Wise & Cui, 2018). Measures of discussion behaviors—both writing and reading—are derived from system log files to describe learner participation and to predict learning performance (Jo et al., 2017; Wise, Hausknecht, & Zhao, 2014). Content analysis is also widely used to assess the quality of post content (e.g., Chen, Chang, Ouyang, & Zhou, 2018; Wise, Hausknecht, & Zhao, 2014).

A subset of these studies are uniquely focused on the *temporal* dimension—which is important conceptually because asynchronous online discussions are transactional and unfold over time. Hesse et al. (1988) delineate four temporal qualities: (a) *temporal scale*—“the scope or duration of events and relationships”; (b) *temporal sequencing*—“the specific patterns of activities within a recurrent or nonrecurrent event”; (c) *pace*—“the rate at which events pass in a specified unit of time” or “an individual's psychological experience of time”; and (d) *temporal salience*—“the degree to which an individual's thoughts, feelings, and actions are past-, present-, or future-oriented” (p. 157). Building on this taxonomy, Wise, Zhao, Hausknecht and Chiu (2014) further contextualize these temporal aspects in online discussions and provided specific

guidance for temporally-aware analysis and design. Such temporally-aware analysis could either focus on a single temporal quality, such as temporal sequencing (Chen, Resendes, Chai, & Hong, 2017), or integrate temporal analysis with other analytical approaches (Häkkinen, 2013). Despite a rising interest in applying temporal analysis in educational research (Chen, Knight, & Wise, 2018), the potential of temporal analysis for examining the participation gap in asynchronous online discussions remains under-tapped.

2.5 The Present Study

The present study explored student participation, and especially the participation gap, in asynchronous online discussions. Within the context of an online undergraduate course, we attempted to determine the extent to which network prestige was reflected in student interactions and, if so, explore its potential contributing factors related to students' post content and posting behaviors. Research questions of the study included:

1. Did students demonstrate varied levels of prestige in online discussion activities?
2. How was prestige reflected in the discussion environment?
3. Which factors could have contributed to the emergence of prestige?

3. Methods

3.1 Research Context and Participants

The study was situated in an undergraduate, fully-online course at a large public university in the United States. As of the study, this course, which covered topics related to technology, ethics, and society, was listed as a liberal-education elective for undergraduate students across the university. One section of this course ($n = 20$) participated in this study. Participating students came from a wide range of disciplines such as psychology, medicine, biochemistry, economics, management, and journalism; they were not concentrated in one college so unlikely to know each other prior to this course.

Informed by social constructivist learning theories, the course design included asynchronous online discussions participated by students weekly on a social learning platform named Yellowdig. Except for the first and last weeks of the semester when the class communicated through a video-based discussion tool (named Flipgrid), students discussed readings and ideas on Yellowdig in the other 13 weeks. By the end of Monday in each week, they were required to minimally contribute one initial post and make two comments on posts from peers. Figure 1 shows an excerpt of the Week 4 discussion prompt provided to students.

Class 4: Information Ethics

The reading for Class 4 is [Norbert Wiener and the Rise of Information Ethics](#), by Terrell Ward Bynum (2008).

Wiener coined the term “cybernetics”

.....

Bynum continues on, making connections between Wiener’s ideas and metaphysics, computer ethics, and humans as social beings. It’s a fairly short article, but also pretty deep stuff, so try to give it a read, then sit down and think for a bit, then give it a reread or two (definitely worth it).

To help frame what you should look for in the reading, consider the two questions for this class:

1. ***How does computer technology contribute to human ‘flourishing’ (as Wiener puts it)?
How does computer technology detract from that flourishing?***
2. ***How have you experienced Wiener’s ‘Human values’ in regards to technology?***

The minimal requirement for Yellowdig participation is to address one question of your choice, but you can answer both if you like. If you choose to address both, I’d ask you to do so in two separate posts (or pins) in order to ensure some depth for each.

Figure 1. Yellowdig discussion prompt for Week 4 of the class.

The discussion environment Yellowdig positions itself as a social learning platform that resembles social network sites such as Facebook and Twitter. As illustrated in Figure 2, students could initiate a post, called *pins* on Yellowdig, which can be *commented* on and *reacted* to (e.g., “Like,” “Love”) by members of the class community. Students could also explicitly *mention* each other in a post or comment (see Figure 2). As of the study, Yellowdig supported only one-level threading, and displayed a new comment on an existing comment as a comment on the top-level post, while the actual student being commented on got mentioned in the new comment. Like most social network sites, Yellowdig was also implemented with a news feed powered by a sorting algorithm, which placed posts with the most recent activities on the top. In comparison with discussion forums found in popular learning management systems (e.g., Moodle and Canvas), Yellowdig provided richer technological features for social interaction.

The instructor’s presence on Yellowdig in this course could be characterized as “high” in the first three weeks and “medium” in the other weeks (Dennen, 2005). To nurture a sense of community, he spent a great deal of time during the first three weeks commenting on students posts (making more than 10 comments per week) and connecting students with each other by mentioning multiple names in a same comment. For the rest weeks, his presence on Yellowdig

was reflected by his reactions (e.g., “liking” a post or comment) and sparse comments (1-2 per week). Overall, he did not dominate the discussion at any point of the semester.

Figure 2. Yellowdig interface. The main interface displays a *post* (also called *pin* on Yellowdig), with its *comments* listed below.

3.2 Data and Analyses

Interaction data on Yellowdig, including 274 posts/pins, 514 comments, 36 mentions, and 74 reactions, were the primary data source. This dataset provided comprehensive information

about students' discussion activities. Course materials, including the syllabus, weekly announcements, and readings, were included as secondary data sources to contextualize primary data analyses.

Social Network Analysis (SNA) was adopted as the main analytical approach. All computational procedures were carried out in R (an open-source computational environment) and its *igraph* package developed for network analysis and visualization. To examine the first question about varied levels of prestige among students, we first constructed a directed social network based on students' commenting interactions on Yellowdig. In the constructed network, each *node* denoted a student and each directed *edge* represented the existence of minimally one comment from one student to another. We did not include mentioning and reacting interactions due to their sparsity. To represent network prestige of each student in the network, we computed *indegree centrality* of each node, which measures the number of nodes pointing towards a particular node (Russo & Koesten, 2005).

To further characterize the manifestation of network prestige, we divided students into two groups with high- and low-level prestige based on indegree centrality. After grouping, we examined group differences in a number of network measures to further characterize prestige in the studied context.

To answer the final research question about potential contributing factors of prestige, we compared two groups in terms of their post content (including length, questioning activity, and readability) and posting behaviors (including timing and temporal dispersion of posts). The choices of these measures were informed by the literature. By contrasting two groups, we sought to tentatively explain the emergence of network prestige in this particular context.

4. Findings

4.1 Descriptive Overview of the Interaction Network

Table 1 presents basic statistics of discussion activities in the whole interaction network involving students and the instructor. On average, each participant authored 13.7 posts and 25.7 comments, and connected with 11 class members for 3.42 times each week. Figure 3(a) presents a visualization of the interaction network, with each node denoting a participant and each edge representing aggregated reply interactions between two participants. The instructor was not found central in the visualized network (see Figure 3(a)); as described earlier, he actively commented on student posts only in the first three weeks.

Network measures in Table 1, particularly network *density* (55%), *centralization* (0.28), and mean *distance* (1.51) (Scott, 2012), indicated that this network was fairly decentralized and well connected for this particular context (Ergün & Usluel, 2016). Students' average *degree*, indicating the number of peers they linked with, was consistently between 3 and 4 across all weeks. The most frequent words used in Yellowdig posts and comments, shown in Figure 3(b), were relevant to course content.

Table 1
Descriptive statistics of the complete commenting network.

Variable	Value
Total posts/pins	274
Total comments	514
Mean degree	20.90
Mean weighted degree	45.40
Mean tie strength	2.07
Network density	0.55
Mean distance	1.51
Degree centralization	0.28

Figure 3. Overview of the interaction network. (a) Sociogram of the whole network. Node size denotes prestige measured by indegree centrality, and node color denotes the group membership (including Group A, Group B, and the Teacher). (b) A word cloud of top words that appeared in post content on Yellowdig.

4.2 Did Students Demonstrate Varied Levels of Prestige in Online Discussion Activities?

Indegree centrality was computed to measure each student's network prestige. The class was then divided into two groups: Group A ($n = 10$) constituted by students with higher indegree centrality ($M = 15.1$, $SD = 2.28$), and Group B ($n = 10$) with students having lower indegree centrality ($M = 5.8$, $SD = 2.97$). As indicated by the varied levels of indegree centrality, Group A students received comments from 15 peers on average, whereas Group B students were commented on by approximately 6 classmates. The average number of comments received by Group A students was 4.28 times as many as Group B students ($M_s = 36.8$ and 8.6).

Despite different levels of indegree centrality, two groups had equivalent *outdegree* and *outgoing interactions*, indicating higher volumes of unreciprocated interactions from Group B students and hence their lower prestige status (Knoke & Burt, 1983). Paradoxically, Group B did

not demonstrate less efforts in forging connections with peers, given their equivalent volume of outgoing interactions, but somehow achieved lower network prestige (lower indegree and fewer incoming interactions) than Group A.

4.3 How Was Prestige Reflected in the Discussion Environment?

Further analyses sought to characterize students' varied levels of prestige from different angles. First, we compared posting activities of two groups. On average, two groups contributed equivalent volumes of posts ($M_s = 14.0$ and 12.6) and comments ($M_s = 25.4$ and 21.0). However, 85.96% of initial posts from Group A were responded, significantly higher than 51.32% of Group B ($t(11.56) = 6.18, p < .001$). Posts created by Group A also received more comments ($M = 2.66$ vs. Group B's $M = 0.71$) and sustained longer discussion activities ($M = 33.15$ hours vs. Group B's $M = 8.69$ hours). Notably, posts shared by two groups received different levels of attention in this class.

Table 2

Independent sample *t*-tests of SNA measures between two groups.

SNA measures	Group A (<i>n</i> = 10)		Group B (<i>n</i> = 10)		<i>t</i>	<i>df</i>	<i>p</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>			
In-degree	15.1	2.28	5.8	2.97	7.84	16.87	0.000***
Out-degree	10.0	1.83	10.9	3.21	-0.77	14.26	0.454
Incoming interactions	36.8	14.0	8.6	5.06	6.01	11.31	0.000***
Outgoing interactions	24.6	3.53	20.8	7.67	1.42	12.66	0.179
Avg. tie strength	2.43	0.51	1.71	0.37	3.62	16.48	0.002**
Betweenness	12.0	8.34	7.22	7.87	1.31	17.94	0.205
Closeness	0.05	0.00	0.04	0.00	4.41	14.61	0.000***
Eigenvector	0.74	0.21	0.33	0.15	5.04	16.10	0.000***
Authority	0.61	0.26	0.12	0.08	5.66	10.51	0.000***
Word count of pins	178	32.6	160	37.8	1.13	17.62	0.274
Word count of comments	34.9	5.05	38.3	14.2	-0.70	11.23	0.499
Percentage of posts being responded	86%	6%	51%	17%	6.18	11.56	0.000***
Average count of comments to a post	2.82	0.87	0.79	0.34	6.89	11.63	0.000***

Note: **— $p < .01$, ***— $p < .001$.

Second, we contrasted several social network indices between two groups. Conceptually, network indices applied in this study may correlate with the prestige measure (i.e., indegree centrality) but would still reveal different characteristics of the network. As shown in Table 2, a *t*-test of the *average tie strength* demonstrated significant difference between two groups ($t(16.48) = 3.62, p < .01$); Group A did not only have more incoming connections but also built stronger ties than Group B. Further comparisons of *closeness* and *eigenvector centralities* also demonstrated significant differences between two groups, favoring Group A; Group A students were closer to peers and connected to peers with higher prestige. Group A students did not have significantly higher *betweenness* centrality, however, showing that they did not do a superior job on bridging peer interactions than Group B students. This finding indicated that those denser and stronger connections of Group A students were likely to be concentrated among themselves instead of benefiting lower-prestige peers.

Given the importance of directionality for network prestige, we further inspected the direction of student interactions and divided the interactions into 4 categories: (1) A→A interactions within Group A, (2) B→B interactions within Group B, (3) A→B interactions from Group A to Group B, and (4) B→A interactions from Group B to A. Results showed that among all directed interactions, 45.20% were A→A interactions, followed by 35.15% B→A, 10.26% B→B, and merely 8.52% A→B. This pattern held true when we inspected temporal changes across weeks (see Figure 4). Notably, Group B students were actively initiating contact with Group A but were seldom reciprocated, and Group A students were more likely to comment on peers with similar prestige.

Figure 4. Four different types of interactions across 13 weeks.

Disparity did not only figure in the presence of connections but also the quality of them, such as *reciprocity* and *persistence* (Vaquero & Cebrian, 2013). Here, we define a connection between X and Y as being reciprocal within one week when an $X \rightarrow Y$ interaction is reciprocated by a $Y \rightarrow X$ interaction during the same week. Analysis of the network identified 59 reciprocal connections across all weeks, which could be further divided into 28 reciprocal connections within Group A, 26 reciprocal connections between Group A and Group B, and the rest 5 within Group B. Among these reciprocal connections, only 16% reciprocal connections were initiated by Group B students, whereas the rest 84% were initiated by Group A. Considering students from two groups initiated equivalent volumes of interactions, it became clear that connections initiated by Group A students were more likely to be reciprocated.

Analysis of persistent connections arrived at similar findings. Given this course's time span, persistent connections in this context were operationalized as connections that occurred in at least five weeks. Among 23 persistent connections found in the student network, 65.22% were within Group A, 30.43% between two groups, and the rest 4.35% within Group B. Further analysis found two unique persistent ties were pointing from Group B towards Group A, and no persistent connections was directing from Group A to Group B. In other words, persistent interactions mostly happened within the high-prestige group, and when they did occur between groups, they were persisted by students in the low-prestige group and not reciprocated by the high-prestige group.

To summarize, prestige manifested in this online class in multiple ways. A series of comparisons found the high-prestige group had more incoming interactions, stronger ties, higher centrality scores, higher odds of being responded, and higher-quality ties—regardless of equivalent measures of outdegree, outgoing interactions, number of posts, and betweenness centrality of two groups. Namely, students from two groups initiated equivalent amount of interactions with equivalent number of peers, but Group A students received significantly more comments than others, occupied more favorable positions in the network, and maintained stronger and higher-quality ties with peers they were connected with—all indicating higher prestige in this network. Their favorable positions were reflected in closeness with peers and being connected with higher-prestige peers (i.e., eigenvector centrality) but not in bridging connections among peers (i.e., insignificant difference in betweenness centrality).

4.4 Which Factors Could Have Contributed to the Emergence of Prestige?

The third research question was concerned with factors that might have contributed to the gap in network prestige. Under the guidance of literature, we inspected a number of factors related to students' post content and posting behaviors, including post length, questioning activity, post readability, and temporal features of posting behaviors.

4.4.1 Post length

Was the disparity in prestige a function of the informativeness of student posts? Did Group A students receive more comments because their posts were longer? Group comparisons of post length found nonsignificant differences in the average length of either initial posts or comments ($ps > .05$).

4.4.2 Questioning activity

Did Group A students receive more replies because their posts were soliciting responses by posing questions? We used the presence of a question mark as an approximate indicator of a question. Results indicated posts shared by two groups did not differ in terms of questioning activity ($\chi^2(1) = 0.02, p = .88$).

4.4.3 Post readability

Prior studies also examined the role played by text readability in online discussion (Zingaro & Oztok, 2012). To gauge the linkage between readability and network prestige, we computed several readability indices, including the Flesch Reading Ease score, the Average Grade Level, and the Automated Readability Index. Contrasts of these readability scores between two groups did not identify any significant difference ($ps > .10$).

Figure 5. Time difference between student pins and the weekly deadlines. The vertical lines indicate Group A students were on average 49.9 hours earlier, while Group B students were 20.7 hours earlier than the deadline.

4.4.4 Temporal features of discussion behaviors

Timeliness of discussion behaviors. Informed by the literature (Hesse, Werner, & Altman, 1988; Wise et al., 2014), we compared the timeliness of student posts in light of weekly deadlines between two groups. As indicated by density curves in Figure 5, most Group B students' posts were barely on time, whereas most Group A students posted one day in advance. Group A and B students significantly differed in the "time delta" of their posts (i.e., the time

difference between a post and the deadline) ($t(246) = -6.15, p < .001$); the same trend was observed for comments ($t(350) = -6.42, p < .001$).

Dispersion of discussion behaviors. Conceptually, dispersion means the extent to which students' posting behaviors were clustered or dispersed compared to the weekly participation timeline (Hesse, Werner, & Altman, 1988). Grounded in this understanding, we computed the *index of dispersion* (Cox, 1966) and compared it between two groups. Results indicated Group A students' discussion behaviors were marginally more dispersed than Group B ($t(151) = 1.85, p = .06$). When inspecting the dispersion index across weeks, we found two groups started from a similar level of dispersion and Group B students' dispersion index declined over the semester, meaning their posting behaviors became increasingly jammed together in later weeks.

Availability of prior posts for commenting. Due to individual differences in the timing and dispersion of participation, each week students might have had different number of available posts to comment on. By reconstructing the discussion context of each individual comment, we found that on average a Group B student would have 9.50 Group A posts and 5.22 Group B posts to comment on, whereas a Group A student would have 6.61 Group A posts and 2.05 Group B posts to respond to. Lower availability of posts from Group B students could have contributed to their lower incoming connections. Because of their different temporal participation patterns, Group A students did not have abundant supplies of Group B students to respond to.

Taken together, while two groups did not significantly differ in post content, they demonstrated significantly different posting behaviors that could have contributed to their varied prestige levels. Discussion contributions made by Group B students were less timely and less temporally dispersed (i.e., more pressed together). These temporal participation patterns could have led to lower availability of Group B posts for Group A students to comment on.

5. General Discussion

In this study, we asked three major questions regarding: (1) Did students demonstrate varied levels of prestige in online discussions? (2) How was prestige reflected in the discussion environment? and (3) Which factors could have contributed to the emergence of prestige? Using indegree centrality as a measure of prestige (Knoke & Burt, 1983; Russo & Koesten, 2005), we found varied levels of prestige reflected in the student network. When students were divided into two groups based on the prestige measure, even if they had equivalent outdegree and outgoing interactions, they differed significantly in incoming interactions. The lower-prestige group did not demonstrate less efforts in connecting with peers but somehow achieved lower network prestige.

To answer the second question, further in-depth analysis was conducted from different aspects. Results showed multiple ways in which prestige manifested in this online class. In particular, posts shared by two groups received different levels of attention. Even though two groups had equivalent measures of outdegree, outgoing interactions, number of posts, the high-prestige group had more incoming interactions, stronger ties, higher centrality scores, higher

odds of being responded, and higher-quality ties. They were closer to peers and were connected with higher-prestige peers but did not help bridge connections among peers.

Analyses responding to the third question attempted to explain the identified gap in network prestige. Factors related to post content, including length, readability, and questioning activity, were nonsignificant predictors. In contrast, two groups were found to differ in micro-level temporal patterns including the timing of posts each week, dispersion of posting behaviors, and availability of posts to be commented on for each group. The high-prestige group generally posted earlier each week, spaced weekly posting activities more evenly, and therefore left peers ample opportunities to react to their ideas. The lower prestige group did the opposite: they posted closer to the deadline, posted hastily, and did not provide peers (especially Group A students) enough time to engage with their posts. Understandably, when the high-prestige group attempted to leave comments, they would have a small number of low-prestige group posts to choose from.

5.1 Scholarly Significance of Investigating Network Prestige and Temporality

Significance of this study ought to be discussed with a few limitations in mind. First, this study is contextualized within a small online class using a uniquely designed discussion environment. Findings about learner participation should be generalized with great caution. Second, this study relied on Social Network Analysis as the guiding methodology, which has its own limits for researching online discussions. For example, while we used Yellowdig log data to construct student networks, prior work found it useful to integrate content analysis to more accurately capture the direction of learner interactions (Manca, Delfino, & Mazzoni, 2009). Third, when analyzing post content we used the presence of a question mark as an approximate indicator of a question. This analytical treatment could be enhanced by manually coding discussion posts or constructing a machine learning model to more accurately identify questions in student posts. Regardless of these limitations, we believe this study has accomplished its goal of calling for attention to network prestige and temporality in asynchronous online discussions.

In the social constructivist paradigm, social participation is treated as an important component of learning, motivating the use of asynchronous online discussions to support student participation in blended and online classes. The study of network prestige in online discussions build on prior work and contributes to the literature in several manners. First, building on prior work on the social dimension of online discussions (e.g., Dawson, 2010; Vaquero & Cebrian, 2013), this study incorporates sociological constructs of prominence and prestige to characterize the participation gap. The use of sociological concepts adds conceptual richness to the literature and encourages future efforts to look into micro-level social patterns and “structural signatures” in online discussions. For instance, while social network metrics such as degree centrality are often used to describe a pattern or to predict learner performance, a closer look at social interaction in group processes based on more sophisticated sociological terms (such as inertia, reciprocity, and transitivity) can further explain the emergence of interaction patterns of interest (Leenders, Contractor, & DeChurch, 2016). This study demonstrates the promise of deeply integrating sociology and network science perspectives in the study of micro patterns in online discussions.

Second, the multifaceted depiction of varied prestige has provided a rich picture of the participation gap that merits further investigation. Earlier research has found social participation in online forums predictive of learning performance (Jo et al., 2017; Joksimović, Gašević, Kovanović, Riecke, & Hatala, 2015; Russo & Koesten, 2005) and low-performing students more likely to connect with similarly low-performing peers (Dawson, 2010; Hu & Zhao, 2016). This study provides detailed depiction of the participation gap. In short, lower-prestige students were attempting to connect with higher-prestige peers but their attempts were not reciprocated. Higher-prestige students were more connected, had more reciprocal and persistent connections, closer to peers, and connected with similarly high-prestige peers; however, they did not occupy more favorable positions in terms of bridging peer connections. Describing the participation gap from different angles is critical for understanding the phenomenon and developing scaffolding strategies for facilitating student participation.

Finally, the uncovered differences in temporal behavioral patterns between high- vs. low-prestige groups merit special attention. Research of online discussions, and education research in general, needs to treat the temporal dimension more seriously (Chen, Knight, & Wise, 2018). The finding that high-prestige students generally posted earlier is in line with the “first-mover advantage” in scholarly communication (Newman, 2009). The temporal patterns that high-prestige students posted early and spaced their participation more evenly also reflect the importance of self-regulation for discussion participation found in prior research (Shea et al., 2013). Overall, the recognition of temporal behavioral patterns as potential contributors to varied prestige contributes to the growing area of temporal analysis in educational research (Chen, Knight, & Wise, 2018).

5.2 Practical Implications

Findings from this study have practical implications for online teaching. The study’s multifaceted depiction of prestige—a sociological construct that captures the directionality and reciprocity of student interaction—offers new angles for instructors and instructional designers to support student participation. For example, current social network analytics tools often provide network visualizations for the instructors to identify students in the peripheral for timing intervention (Chen, Chang, Ouyang, & Zhou, 2018). However, network visualizations in these tools cannot fully capture prestige differences uncovered in this study. In particular, students who actively initiate unreciprocated contacts with others and hold less prestige will actually appear in the center of a typical “force-directed” network visualization. This study urges instructional attention paid to not only peripheral students who are less connected but also low-prestige students whose attempts to connect are not responded favorably by peers.

The finding that high-prestige students tend to space their efforts more evenly implies the possibility of offering additional scaffolds such as suggesting all students to check-in for a couple of times each week. Being able to tactfully plan forum participation reflects strong self- and co-regulation skills that are linked with more central positions in discussion networks (Shea et al., 2013). Stronger supports are needed to help students develop such advanced skills conducive to productive participation behaviors and dispositions.

In terms of technological design, temporal patterns identified in this study hint the importance of temporal salience—ways in which discussion participation is temporally-oriented (Hesse, Werner, & Altman, 1988)—that gets built in technological environments like Yellowdig. Optimally, technological designs are embedded within themselves intelligence to support human interactions and help distribute cognitions between human and computers (Pea, 1993). In this study, we recognized that technological features of Yellowdig carried out important cognitive acts for the class. For instance, Yellowdig's sorting algorithm, which placed posts with the most recent activities on the top of the "news feed," might foster more dynamic interactions than traditional threaded forums (which require users to track discussions by themselves). In the same time, however, we conjecture that this sorting algorithm could have also contributed to varied prestige. In particular, the sorting algorithm's emphasis on recency can lead to the dying of inactive posts (Hewitt, 2005), especially undermining Group B students in our case because their posts were commented on less frequently and their participation was compressed together. Thus, we call for stronger reflexivity of tool designers on the temporal aspect of user experiences and future research to consider the hybridity of temporal features in a discussion environment and learners' discussion dispositions and behaviors (e.g., being inclined to comment on more recent posts).

5.3 Future Directions

Much future work needs to be done in order to advance the analysis of network prominence and prestige in asynchronous online discussions. First of all, the temporal aspect of student contributions examined in this study needs further investigation to understand why students demonstrated different timing behaviors and how a student chooses a particular post to respond to in Yellowdig's recency-based sorting algorithm. Even though the present study drew from Social Network Analysis (a predominantly quantitative methodology), qualitative methods would be extremely valuable for answering these questions. Second, findings from this study also hint possible fruitfulness of studying students' self- and co-regulation strategies in online discussions. It could be especially fruitful to design formative feedback tools to help students regulate their discourse participation (Chen, Chang, Ouyang, & Zhou, 2018). Finally, we also question whether the traditional weekly-based course design is doing justice to discussion-centric online learning and call for innovative course designs that can break temporal boundaries set by the week-based academic calendar. If new cultures of learning emphasize social participation in knowledge "flows" instead of the acquisition of knowledge as "entities," structures imposed by traditional institutions would better be challenged.

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