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Students Interactions and Course Performance: Impacts of Online and Offline Networks

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Students’ Interactions and Course Performance: Impacts of Online and Offline Networks

Interactions des étudiants et performance : Impacts des réseaux en ligne et hors-ligne

Completed Research Paper

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Abstract

This paper takes a social network approach to understand students’ interactions and their course performance. Drawing from media richness theory and media synchronicity theory, we distinguish students’ online and offline communication networks to theorize the relationship between network structure and students’ course performance. Particularly, we examine a specific property of the network structure, i.e., closeness centrality, defined as the extent to which a student is close to other students in the network and thus relates to the ease of access an individual has to others. We explain the interdependence of online and offline networks and theorize about how it is associated with students’ course performance. A study of 52 students in the People’s Republic of China (P.R.C.) supported our theory.

Keywords: online, offline, closeness centrality, students’ interactions, course performance
Résumé

Cette étude mobilise l’approche des réseaux sociaux pour comprendre les interactions des étudiants et leur performance. En se basant sur la théorie de la richesse des médias et la théorie de la synchronicité des médias, nous distinguons les réseaux de communication en ligne et hors ligne pour étudier la relation entre la structure du réseau et la performance des étudiants.

Introduction

Interactions and collaborations among students could positively (Doise et al. 1975; Webb 1982) or negatively (Baldwin et al. 1997; Michaelsen et al. 1993) influence their course performance. Therefore, it is important to understand the circumstances under which students’ interactions will yield improved course performance. To get a better understanding of students’ interactions, we need to know the patterns of their interactions, i.e., with whom they interacted, directly or indirectly, and how—i.e., face-to-face (FTF) or virtual communication, and understand what the effective patterns of interactions will be. Social structures serve as an effective proxy for such interpersonal interactions. The understanding gained from a social structure perspective alone will be insufficient as it does not incorporate media choice in communication. However, little research has combined literature in social structure and communication media in understanding students’ interactions and their course performance.

Prior studies have shown that students interact with each other more effectively when a social structure enables them to access a larger base of contacts and makes the exchange of information faster (e.g., Baldwin et al. 1997; Cho et al. 2007; Ortiz et al. 2004; Yang and Tang 2003). To conceptualize and theorize about social structures, prior research has employed social network theory (e.g., Borgatti 2005; Burt 1992; Freeman 1979; Granovetter 1973) as it describes the relationship between social network structure and social interactions. When students interact with each other, they also transform the network structure in which they are embedded and such network structure will in turn enable or constrain their interactions. For example, students may create more links or change an indirect link to a direct link through interaction. When the structure of the network changes, the way students interact with each other changes accordingly. Drawing from prior research, we will apply social network theory to understand students’ interactions and their course performance. Further, we extend prior research on social networks by drawing from media richness theory (Daft and Lengel 1986) and media synchronicity theory (Dennis and Valacich 1999; Dennis et al. 2008) to distinguish students’ online and offline networks to understand how different patterns of networks are correlated with academic performance. Moreover, distinguishing online and offline networks makes it possible to examine how online and offline networks relate to each other in terms of affecting students’ interactions and their course performance. Specifically, we draw from the theory of complementarity (Milgrom and Roberts 1995) that explains how complementary resources result in enhanced performance outcomes that are far beyond the simple additive effect of these resources, to argue students’ online and offline networks are complementary in terms of affecting students’ interactions and their course performance.

The relationship between network structure and students’ course performance has been examined in prior studies that have found that students who occupied central positions in various networks, e.g., communication network, advice network, friendship network or collaborative learning network, achieved better course grades (e.g., Baldwin et al. 1997; Cho et al. 2007; Yang and Tang 2003). One major advantage of occupying a central position is that a student is thus proximal to other students in the network, i.e., closeness centrality (Borgatti 1995, 2005). “An individual who is maximally close would have direct, unmediated relationships with all other members of the network” (Baldwin et al. 1997, p. 1372). Prior research theorized a positive relationship between closeness centrality and students’ course performance (e.g., Baldwin et al. 1997; Cho et al. 2007), and closeness centrality is conceptualized as “ease of access to others” (Burkhardt and Brass 1990, p. 113). When individuals are close to others in the network, they are occupying a network position easier for information access, in terms of getting access to larger quantity and higher quality information (Baldwin et al. 1997) and receiving the information faster (Burt 1992). Therefore, closeness centrality can be regarded as a proxy for fast receipt of information. While prior research has noted the importance of fast receipt of information, it has not explained why fast receipt of information affects students’ course performance. In this paper, we will extend the discussion on fast receipt of information by theorizing why it affects students’ course performance. Given that we apply media richness theory and media synchronicity theory in distinguishing students’ online and offline networks to theorize how structures
of both networks affect students’ interactions and course performance, it is relevant to emphasize the concept of fast receipt of information, which is consistent with the idea of immediate feedback highlighted by both media richness theory and media synchronicity theory.

Our work is expected to make important contributions. First, we bring insights of media richness theory and media synchronicity theory into social network theory in the context of understanding students’ interactions and their course performance. Drawing from media richness theory and media synchronicity theory, we distinguish between students’ online and offline networks to theorize the relationship between network structure and students’ course performance. Second, our research contributes to social network theory by extending our understanding of the concept of fast receipt of information. The current research extends our understanding of this concept by providing the theoretical justifications for the relationship between fast receipt of information and students’ course performance. Also, by differentiating online and offline networks, we conceptualize and theorize closeness centrality at a more granular level, thus extending our understanding the role of this network property. Third, this research seeks to understand the implications for system design, more specifically, how to improve the design of an e-learning collaborative system that can facilitate students interactions and enhance their course performance. Even though network structures are subject to change, they would be stable for a certain period of time and people’s interactions will be affected by such temporarily stable network structures. Once network structures change, it will still affect people’s interactions, probably in a different way, depending on how the structures have changed. Prior research has examined how network structures affect people’s interactions. For example, a dense network can reduce the obstacles to initiate coordination and can result in more interactions among actors than a sparse network can (e.g., Obstfeld 2005). A wealth of research has examined different types of network (e.g., friendship, advice, information) to understand how different network structures affect interactions and behaviors (e.g., Baldwin et al. 1997; Borgatti and Cross 2003; Cho et al. 2007; Obstfeld 2005; Reagans and McEvily 2003; Yang and Tang 2003).

An important structural property is network centrality that describes an individual’s position in the network, i.e., the extent to which the individual is linked to others in the network (Ahuja et al. 2003). Centrality is a key concept in social networks (Rogers and Kincaid 1981) that has been conceptualized with different dimensions that describe an individual’s network position from different perspectives: e.g., degree centrality—i.e., number of immediate ties or

Theoretical Background and Hypotheses

In this section, we describe the three related yet distinct theoretical lenses used in this research. While the social network perspective provides us the structural view that relates to human behaviors, the media richness and media synchronicity theories make such structural view more complete by explaining the formation and the change of such structure. Finally, the theory of complementarity enriches our understanding of the structural view by explaining how different structures complement each other.

Social Network Theory

A social network is “a specific set of linkage among a defined set of persons, with the additional property that the characteristics of these linkages as a whole may be used to interpret the social behavior of the persons involved” (Mitchell 1969, p. 2). A network approach describes pattern of interaction between persons as a graph of connections between persons (Newman 2002), whereas individual actors within the network are called nodes, and relationships between actors are called ties. Nodes and ties form the structure of the network and social network theories describe the network structure as resources for social action (Baker 1990; Bourdieu 1986; Burt 1992; Coleman 1988, 1990; Jacobs 1965; Loury 1987). More specifically, social network theory seeks to understand the nature of a network (i.e., network patterns), its antecedents, and consequences at different levels, e.g., interpersonal, interunit or interorganizational (Brass et al. 2004).

The social network approach argues that the structure of the network will explain an individual’s behavior in a social framework beyond what is explained by the characteristics of the individual, as most behavior is closely embedded in networks of interpersonal relations (Granovetter 1985). The patterns of a network will have a significant impact on how people interact with each other. Even though network structures are subject to change, they would be stable for a certain period of time and people’s interactions will be affected by such temporarily stable network structures. Once network structures change, it will still affect people’s interactions, probably in a different way, depending on how the structures have changed. Prior research has examined how network structures affect people’s interactions. For example, a dense network can reduce the obstacles to initiate coordination and can result in more interactions among actors than a sparse network can (e.g., Obstfeld 2005). A wealth of research has examined different types of network (e.g., friendship, advice, information) to understand how different network structures affect interactions and behaviors (e.g., Baldwin et al. 1997; Borgatti and Cross 2003; Cho et al. 2007; Obstfeld 2005; Reagans and McEvily 2003; Yang and Tang 2003).
the extent to which an individual is linked to others in the network; betweenness centrality—i.e., number of shortest paths that pass through an individual or the extent to which an individual controls knowledge flow; and closeness centrality—i.e., sum of the shortest paths from an individual to all other individuals or the extent to which an individual is proximal to all others in the network (Borgatti 1995, 2005; Freeman 1979). Thus, centrality describes how an individual connects to others in the network, i.e., to whom the individual is connected, number of direct and indirect connections, and distance between the individual and others.

Understanding structure in this fashion sheds light on the interaction patterns of the individual. For example, if an individual has many links in the network, he or she would have a greater chance of interacting with others. The individual can initiate the interaction by contacting others, or being contacted by others. In the context of understanding students’ interactions and their course performance, prior studies have shown that closeness centrality has a stronger relationship with course performance than has other centrality dimensions (e.g., Baldwin et al. 1997; Cho et al. 2007; Ortiz et al. 2004), thus indicating ease of access to others is important for effective interactions. Consistent with prior studies, this paper uses closeness centrality to explain students’ interactions and course performance.

**Media Richness Theory and Media Synchronicity Theory**

Media richness theory presents a framework to explain the choice of communication media by managers for information processing (Daft and Lengel 1986). The fundamental assumption of this theory is that organizations need to use large amount of information that is communicated through various media (Galbraith 1977). The effectiveness of information distribution depends largely on the communication medium used given that different communication media possess different capabilities. Media richness theory emphasizes richness as the key feature for communication effectiveness. Richness is used as an index that assesses the capability of the medium in terms of clarifying ambiguity and amplifying understanding in a timely manner (Maruping and Agarwal 2004). Media richness theory describes that media differ in “richness” in terms of its ability to transmit multiple cues, immediacy of feedback, language variety and personal focus of the medium, and it argues FTF communication is the richest medium. Compared to FTF communication, online communication transmits fewer social cues and reduces the effect of personal focus.

Similarly, media synchronicity theory not only suggests media differ in richness but also provides more information about the conditions under which the efficacy of each medium varies, i.e., it emphasizes the task and social context which place different demands on different functionalities of the medium. Moreover, it extends media richness theory by capturing three additional capabilities of a medium, i.e., parallelism, reprocessibility, and reheasability (Dennis and Valacich 1999; Dennis et al. 2008). Parallelism refers to a medium’s capability of supporting multiple and simultaneous conversions. Reprocessibility refers to a medium’s capability of supporting reexamining and revisiting a message. Reheasability refers to a medium’s capability of supporting reediting and refining a message before sending it out.

As media richness and media synchronicity theories explain communication effectiveness along different dimensions, we draw from both theories to understand students’ online and offline interactions and conceptualize their online and offline networks. Media richness and media synchronicity theories can shed light on our understanding of the relationship between students’ interactions and their social networks. While interpersonal interactions have a significant impact on the formation and development of a social network (e.g., effective interpersonal interactions may create strong ties, larger network size, or result in occupying strategic network positions), the effectiveness of interpersonal interactions is largely dependent on the effectiveness of communication that is in turn affected by the media people use to communicate with each other.

In today’s educational environment, FTF interactions are supplemented and even replaced by interactions using various communication technologies (e.g., Han and Hill 2007; Teo et al. 2003; Xie et al. 2006). A recent study indicated that communication styles significantly influence various communication behaviors (Cho et al. 2007) and certain students may prefer to use online communication over FTF communication, probably because of their own deficiencies in FTF communication, such as concern about face-loss and fear of status differences. Another study indicated formation of membership would facilitate students’ collaborative learning in an online environment (Han and Hill 2007). In contrast, FTF communication becomes more effective when interpersonal interaction requires transmission of multiple cues, immediacy of feedback, language variety, and personal focus.
For example, FTF communication would be more effective in terms of using immediate feedback and high variety natural language to clarify misunderstanding (Dennis and Valacich, 1999; Dennis et al. 2008).

Some online communication media are better than the FTF medium in terms of supporting parallelism, reprocessibility, and rehearsability. When people communicate FTF, they cannot start multiple conversations at the same time, but some group support systems are specifically designed to enable that, thus better supporting message parallelism. Also, some online media (e.g., online discussion forum) are better than the FTF medium in terms of documenting the conversation history for future reference, thus better supporting revisiting and reprocessing of past communication records and enhancing the capability of file sharing. Unlike FTF conversation, people using email can edit the messages many times to make sure the messages are clear before they send them out, thus better supporting message rehearsability. If students are proficient in using online communication media, they may use them extensively to interact with other students.

This indicates communication media with varying capabilities affect students’ interactions, such that some students could be better off with offline interactions and others could be better off with online interactions. If students interact more effectively with others offline, they may establish more offline connections and thus build a larger offline network. Similarly, if students interact more effectively online, they may establish a larger online network. Different online and offline network structures are thus developed. Moreover, some students may intend to build both networks. Prior studies have indicated people use communication technologies to maintain or strengthen their existing FTF network (e.g., Hampton and Wellman 2002; Mesch and Levanon 2003; Wolak et al. 2003). For example, students not only meet FTF, but also email each other such that communication is not constrained by space and time. Some students may use communication technologies to expand their existing offline network. To maintain a sizable FTF network is not easy as it takes time and effort to do so, e.g., need to be at the same time and at the same place. Therefore, as the size of network grows, the percentage of their FTF communication decreases. However, use of communication technologies may resolve this problem by reducing the cost of maintaining relationships. A study indicated that as the size of people’s network grows, the percentage of their network contacted through email does not decline (Boase et al. 2006). Internet users have larger networks than do nonusers (Boase et al. 2006). For American Internet users, the median size of the core network is 37, whereas for non-users, it is 30 (Boase et al. 2006).

**Theory of Complementarity**

The theory of complementarity (Milgrom and Roberts 1995) is rooted in the resource based view of organizations. A fundamental tenet of this theory is that synergies or fit of firm resources (e.g., human, technology, practice, strategy, etc.) lead to enhanced firm performance. Fit indicates resources are complementary. When there is a fit, the impact of these complementary resources on the performance outcome is far beyond the simple addition of these complementary resources. For example, it was proposed when organizations adopt human management practices that complement and support each other, firm performance will be enhanced (Baird and Meshoulam 1988). In another study, complementarity is conceptualized as one of the important dimensions for value creation in e-business (Amit and Zott 2001). To apply complementarity theory, we assume factors being studied complement to each other, i.e., the effect of one factor may be strengthened by the presence of another factor. In the discussion of students’ communication networks, we distinguish between online and offline networks. One major benefit of distinguishing between online and offline networks is that we can examine their complementary effect. In other words, we apply complementarity theory to understand students’ interactions and their course performance.

**Closeness Centrality and Course Performance**

While students’ online and offline communication networks are transformed by different communication media, both these networks will play an important role in affecting interactions among students. Students’ interactions can be considered as social action that is bound by their network structures. As noted earlier, we focus on one structural dimension, i.e., closeness network centrality, and understand how it relates to students’ course performance. Closeness centrality represents ease of access to others. An individual who is close to others in the network will receive information faster if the following two assumptions are satisfied: first, flows start from all other nodes with equal probability, and second, among all the possible paths from two nodes, message will flow through the shortest path (Borgatti 2005). Other things being equal, an individual who has shorter distances from others is more likely to receive information earlier.
Prior studies have indicated fast receipt of information affects knowledge transfer and task performance. For example, in an experimental study conducted by Dihoff et al. (2004), students who were provided with immediate feedback performed better in academic tests than those who were not. Other studies indicated early feedback was related to efficient retention of knowledge (Phye and Andre 1989), acquisition of verbal materials (Ammons 1956), and motor skills (Anderson et al. 2001; Brosvic and Cohen 1988). But in these studies, fast receipt of information is not conceptualized as a structural property of the network, and more importantly, the rationale for why fast receipt of information affects performance outcomes have not been given. Some network studies indicated a positive relationship between closeness centrality and students’ course performance, but closeness centrality was conceptualized as ease of access to others along the dimension of access to larger quantity and higher quality information, rather than focusing on fast receipt of information (e.g., Baldwin et al. 1997; Cho et al. 2007). The question of why fast receipt of information relates to students’ course performance remains unclear, for which we provide the following rationale.

First, the sooner the students get the information, the easier for them to make sense out of it. Information processing theory (e.g., Bettman 1979; Tybout et al. 1981) suggests that incoming information will trigger prior processed information stored in the active memory of human brains for current information processing. Such prior processed information is most likely related to the current information and thus is helpful in understanding the current information. Therefore, the effectiveness of current information processing is affected by how much relevant information can be recalled from the past. However, the capacity limit of the active memory will restrict the amount of information that can be stored for a long time. This suggests the prior processed information may not be kept for a long time such that it may not be recalled and used for current information processing. When students ask questions, they expect to receive the answers in a short time when they still have vivid memory of the questions. If it takes too long to get answers, they may have forgotten many relevant details of their questions and it requires extra time to relate their questions to the answers, thus increasing the difficulty of understanding the knowledge. This relates the storage time in brain to the communication time between students because the usefulness of the former is likely to be affected by the latter. For example, if a student has a question when doing a biology lab experiment and the answer to the question is related to some experimental conditions, such as temperature, humidity and sequences of operation, it would be better to get the answer immediately before the memory of experimental conditions become vague and affect knowledge transfer.

Second, it would be ideal to solve a problem at the time it is raised; otherwise the motivation for solving the problem would fade, probably because the problem would appear less relevant and salient over time, or because the attention has shifted to other problems. Prior studies indicated a positive relationship between motivation and course performance (e.g., Lin et al. 2001). As an example, when students cannot resolve the problems before a deadline, they may lose the motivation to resolve the problems when there is no urgency to meet a deadline. Therefore, it would be ideal for the questions to be answered the soonest possibly, at the time when people are motivated and are likely to work harder on resolving the problem and absorbing new knowledge.

Third, timely information helps students complete their course-related tasks without delay. Such information is supposed to help students resolve task-related problems. When such information is received late, students may not be able to complete their tasks on time, resulting in a lower course grade. Finally, fast receipt of information is related to information quality. Fast exchange of information affects communicative effectiveness because timely exchange of information helps clarify misunderstandings between the source and the recipient. Failure to clarify misunderstandings may result in drawing incorrect conclusions. When the source and recipient are dissimilar, (e.g., different knowledge level), they are more likely to misunderstand each other (e.g., Massey and Montoya-Weiss 2006). Under such circumstances, frequent and timely communication is necessary to clarify such misunderstandings and facilitate knowledge transfer. Moreover, it takes more time to receive the information if the path lengths between the source and recipient increase. In this case, the integrity of the message will be reduced because the more nodes in the network a message needs to pass through before it reaches the target, the more noise and interference to which it will be exposed, and the more deviant the message will be from what was started by the original source. Thus, individuals who are proximal to others in the network will receive more accurate information and perform better.

H1a: Offline closeness centrality will be positively related to students’ course performance.
H1b: Online closeness centrality will be positively related to students’ course performance.

In addition to the individual impact of online and offline closeness centrality, we theorize how they interact with each other to create a synergistic effect on students’ course performance. The economic theory of complementarity (Milgrom and Roberts 1995) that indicates that a set of complementary resources produces greater return than the sum of their individual returns, and media richness theory (Daft and Lengel 1986) and media synchronicity theory (Dennis and Valacich 1999; Dennis et al. 2008) that explain varying communicative capabilities associated with different communication media can help us understand the synergistic effect of the online and offline networks on students’ course performance.

On the one hand, online communication may remove some communication barriers inherent with offline communication. One major barrier is that people may not always be available to meet FTF. Another barrier is that generally only one person can speak or people need to speak one after the other in FTF meetings. In this case, some people may not have the chance to speak, thus reducing the possibility for other people to listen to or learn from these people. Some computer-mediated technologies resolve this problem by supporting parallel communication (Dennis and Valacich 1999; Dennis et al. 2008). Also, online communication activities are usually better documented such that communication history can be revisited (Dennis and Valacich 1999; Dennis et al. 2008; Majchrzak et al. 2005) to clarify confusion due to vanishing memory when needed. Therefore, online communication is complementary to offline communication. On the other hand, offline communication plays a critical role in terms of affecting communication effectiveness. To be effective in transferring knowledge among students, it is important to clarify misunderstandings during communication. According to media richness and media synchronicity theories, FTF communication is better than computer-mediated communication to clarify misunderstandings. FTF communication can convey useful contextual information that is difficult to be conveyed online and knowing such contextual information may help clarify misunderstandings. In addition, media richness theory suggests that FTF communication is associated with the highest level of personal focus (Daft et al. 1987). As people generally pay more attention to the conversation when there is a high level of personal focus, they may have a better understanding with each other. As online and offline closeness centrality will create a synergistic effect that facilitates knowledge transfer, we argue the optimal network structure is being central in both networks. Therefore, we hypothesize:

H2: There is an interactive effect between online and offline closeness centrality on students’ course performance such that students who are central in online and offline networks perform better than those who are only central in online or offline networks.

Further, we argue that offline centrality with students’ course performance than has online centrality. By nature, human beings seem to favor FTF communication. Drawing from Darwin’s (1859) theory of evolution of species, Kock (2004, p. 331) explained such preference and stated human’s “biological apparatus, which includes sensory and motor organs used for communication as well as brain functions associated with these organs, must have been designed primarily for face-to-face communication”. He further argued the more similar the communication medium to the FTF medium, the less cognitive effort is required from an individual using the medium for knowledge transfer. Meanwhile, students may not be able to use the right communication technologies for different communication requirements. When there is a mismatch between students’ communication requirements and the technology used, communication effectiveness will be reduced and knowledge transfer will be hampered.

In addition to biological adaptation, FTF communication is deemed to be more effective than communication using other media in clarifying misunderstandings and establishing mutual knowledge. Media richness theory argues FTF communication is the richest communication medium that supports transmission of multiple cues, immediate feedback, and various languages, and increases personal focus. During FTF meetings, students can use all kinds of cues (e.g., verbal, visual, sensory) to convey or interpret information and thus increase mutual understanding that has been shown to have a significant impact on knowledge transfer (e.g., Ko et al. 2005; Levin et al. 2006). Failure to clarify misunderstandings and establish mutual knowledge may result in relational conflict, which is more likely to occur when using online communication. A study by Cramton (2001) on virtual teams found that using online communication resulted in frustration or dissatisfaction that hinders knowledge transfer. Other studies have also indicated similar results, i.e., people have more conflicts and are less satisfied when using computer-mediated technologies (Chidambaram 1996; Hinds and Mortensen 2005; Poole et al. 1991). Finally, FTF communication is more effective in transferring tacit knowledge. Transferring tacit knowledge requires intensive interpersonal
interaction that would be difficult to carry out using online media. For example, Griffin et al. (2003) have indicated the difficulty for virtual teams to transfer tacit knowledge as they do not have much opportunity to meet FTF. In fact, methods that are effective in transferring tacit knowledge, such as mentoring or apprenticeship, rely mainly on FTF communication. Therefore, we hypothesize:

H3: Offline closeness centrality will be more strongly correlated with students’ course performance than will online closeness centrality.

Research Methodology

Sample and Procedures

Participants of this study comprised sophomores majoring in microbiology in the People’s Republic of China (P.R.C.). We invited 55 students who took the same class to participate in the study and 52 of them filled out our surveys, with a response rate of 95%, which is above the 80% response-rate threshold in network studies (Wasserman and Faust 1994). Of the 52 respondents, 24 were men and 28 were women, with the age ranging from 17 to 23 (M = 20.33 years, SD = .99 years).

We coordinated with the instructor to schedule a class period for data collection, except for one class wherein data were collected via email. Also, we asked the instructor to give us the names of students who registered for the class to create the roster, which is a standard approach to collect network data. Our surveys were distributed during the scheduled class periods and it took about 40 minutes for a student to fill out a survey (including additional filler questions, such as other personality dimensions). Data were collected at the end of the semester right before the final test period. Throughout the semester, students had sufficient opportunities to interact with each other online and offline. As a result, the network structure at the end of the semester is likely to be more stable and defined. Therefore, it will be more valid to examine the relationship between network structure and course performance at that point in time. To increase participation, we offered incentives for participation. The survey was administered in Chinese. To minimize translation errors, the original survey written in English was first translated into Chinese and then back translated into English and the few discrepancies found were discussed and resolved. To collect the online and offline communication network data, we asked students to respond to specific questions about other students they knew. We used the whole network design to improve the reliability of network data (Marsden 1990; Scott 2000). One item was used for each network because using multiple items would be too demanding and would result in respondent fatigue and poor response rate (e.g., Marsden 1990; Venkataramani and Dalal 2007).

Measures

Online and Offline Closeness Centrality

We used different rosters to measure online and offline communication related to coursework. Online communication refers to any communication via email, instant messenger or mobile text messaging. Offline communication refers to face-to-face communication. Online communication was measured using the question “On average, I communicate with this person online…” and offline communication was measured using the question “On average, I communicate with this person offline…” Participants were asked to respond to these questions using a Likert-type scale ranging from 1 to 5 (1 = less than once a month, 2 = once a month, 3 = once a week, 4 = once a day, 5 = many times a day). Consistent with prior network research (e.g., Ahuja et al. 2003; Cross and Cummings 2004; Sparrowe et al. 2001), we used data about the in-degree network to minimize the bias of self-reported data. For example, if we want to measure the frequency of students’ online communication with others, we did not use their self-reported data, but instead we use the report of other students who reported the frequency of being contacted. Closeness centrality was calculated using the UCINET 6.0 software used in network analysis (Borgatti et al. 2002) for online and offline networks respectively. Specifically, Freeman (1979)’s method of undirected geodesic distance was used to calculate each student’s closeness centrality, i.e., the sum of the geodesic distances for each student.

Course Performance

Course performance was measured using students’ course grades (measured on a 100-point scale) provided by the instructor of the course.
Control Variables

We included age, gender, computer experience (i.e., years of using computer), computer self-efficacy, and conscientiousness as control variables. Gender was coded using a binary dummy variable, with male coded as 1 and female coded as 0. We used a 4-item, 7-point scale computer self-efficacy measure adapted from Venkatesh et al. (2003). An example item is “I could complete a job or task using a computer if there is no one around to tell me what to do as I go.” The Cronbach alpha for this scale was .81. We used a 10-item, 5-point scale conscientiousness measure developed by Gosling et al. (2003). An example item is “I am always prepared.” The Cronbach alpha for this scale was .76.

Results

Table 1 provides means, standard deviations and intercorrelations (i.e., Pearson correlation) among study variables. As we can see, online closeness centrality is significantly correlated to offline centrality ($r = .73, p < .01$), indicating the similarity between the online and offline networks. Also, both online ($r = .29, p < .05$) and offline ($r = .35, p < .05$) centrality is significantly related to course grade in the expected direction. We also examined the extent of overlap between online and offline networks. We found the overlap to be about 70%, indicating the possible distinction between online and offline networks.

Hierarchical moderated regression analyses were performed to test the hypotheses because we want to study how much variance is explained by network variables that is beyond the control variables. We first included gender, age, computer experience, computer self-efficacy, and conscientiousness as control variables, followed by the main effects, i.e., online and offline closeness centrality, and finally, the interaction effect between online and offline centrality. As suggested by Aiken and West (1991), we also mean centered the variables included in interaction terms before performing the analyses. The regression results are presented in Table 2.

Results indicate offline closeness centrality had a significant and positive relationship with class performance ($b = 2.23$, $p < .05$), but the relationship between online closeness centrality and class performance was not significant ($b = .35, p > .05$), thereby hypothesis 1a was supported but hypothesis 1b was not supported. Also, there was a significant interaction effect between online closeness centrality and offline closeness centrality ($b = .20, p < .05$) and is plotted in Figure 1. The interaction plot suggests the best scenario was being central both online and offline, the second best scenario was being central offline. When offline centrality is low, there was not much performance difference between high online centrality and low online centrality. Therefore, hypotheses 2 and 3 were supported.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>S.D.</th>
<th>1</th>
<th>2</th>
<th>3</th>
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<td>1. Age</td>
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<td>.50</td>
<td>.40**</td>
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<td>3. Computer experience</td>
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<td>3.34</td>
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<td>4. Computer self-efficacy</td>
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<td>-.06</td>
<td>-.07</td>
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<tr>
<td>5. Conscientiousness</td>
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<td>-.00</td>
<td>-.03</td>
<td>-.06</td>
<td>-.01</td>
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<td>6. Online closeness centrality</td>
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<td>10.60</td>
<td>.01</td>
<td>.17*</td>
<td>.24*</td>
<td>-.13</td>
<td>-.27</td>
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<tr>
<td>7. Offline closeness centrality</td>
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<td>6.45</td>
<td>-.11</td>
<td>.11</td>
<td>.28*</td>
<td>.03</td>
<td>-.14</td>
<td>.73**</td>
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<tr>
<td>8. Course grade</td>
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<td>7.06</td>
<td>-.15*</td>
<td>-.37**</td>
<td>-.42**</td>
<td>.02</td>
<td>.11*</td>
<td>.29*</td>
<td>.35*</td>
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</table>

Notes: Gender was coded 0 (female) and (male). N=52.

1 Closeness centrality is the sum of geodesic distances for an actor in the network. A smaller the number indicates shorter distance (i.e., the actor is closer to all others in the network) and higher closeness centrality. We reversed the coding of centrality such that high larger value indicates higher closeness centrality. This makes the interaction plot in Figure 1 easier to interpret.
Table 2. Hierarchical Moderated Regression Analyses

<table>
<thead>
<tr>
<th>Step 1</th>
<th>DV: Course Grade</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
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<tr>
<td>Age</td>
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<td>-3.70*</td>
<td>-3.12</td>
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<td>Computer experience</td>
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<td>-0.93***</td>
<td>-0.89***</td>
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<tr>
<td>Computer self-efficacy</td>
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<td>0.60</td>
<td>0.50</td>
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<tr>
<td>Conscientiousness</td>
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<td>0.70*</td>
<td>0.54</td>
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<tr>
<td>R²</td>
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<td></td>
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</tbody>
</table>

Step 2

<p>| | | | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Online closeness centrality</td>
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<td>0.70</td>
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</tr>
<tr>
<td>Offline closeness centrality</td>
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<td>2.42*</td>
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</tr>
<tr>
<td>R²</td>
<td>0.33</td>
<td></td>
<td></td>
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<tr>
<td>Δ R²</td>
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Step 3

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<tbody>
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<td>Online closeness centrality X offline closeness centrality</td>
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<td></td>
</tr>
<tr>
<td>R²</td>
<td>0.39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ R²</td>
<td>0.06*</td>
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</table>

Notes: Unstandardized regression coefficients are shown above. N=52.

* p < .05, ** p < .01, *** p < .001.

Figure 1. Interaction of Online and Offline Closeness Centrality on Course Performance
Discussion

Summary of Key Findings

This study seeks to advance our understanding of students' interactions and their course performance from a social network perspective. Specifically, we examined how the closeness centrality of students’ online and offline communication networks correlate with their course performance. Based on student samples from the P.R.C., most of our hypotheses were supported. Offline closeness centrality was found to be positively related to course performance and the correlation was significant. Online closeness centrality was found to be positively related to course performance but the correlation was not significant. In addition, there was a significant interaction between online and offline closeness centrality. When both online and offline closeness centrality were high, students had the best course grades, indicating a synergistic effect. The second best scenario was when the students had high offline centrality but low online centrality. Finally, the worst scenario was when the students had low offline centrality. In this case, there was not much difference in their course grades, regardless of whether they had high or low online centrality, suggesting that offline centrality is more important than online centrality in determining course performance.

Theoretical Implications

This study contributes to research in several ways. First, our paper demonstrates that the social network lens is pertinent to understand students’ interactions and their course performance. As the centerpiece of social network theory, social network structure is the focus of network studies. On the one hand, network structure is transformed by social interactions. For example, students may create new connections or alter old connections (e.g., from indirect connection to direct connection) when they interact with each other. On the other hand, network structure enables and constrains social interactions. For example, if students are central in the network, they would have more connections and hence are more likely to interact with others. In contrast, students who occupy peripheral network positions would have fewer connections and are less likely to interact with others. Learning is an interactive process and students’ interactions affect their course performance. In view of the important role of social structure in affecting students’ interactions, it is relevant to apply a network approach to understand students’ interactions and their course performance.

Second, our paper indicates bringing insights from media richness theory (Daft and Lengel 1984, 1986; Daft et al. 1987) and media synchronicity theory (Dennis and Valacich 1999; Dennis et al. 2008) into social network theory is a potential way to extend social network theory. This paper points out the relevance and importance of applying media richness theory and media synchronicity theory to study social structures and social interactions. Drawing from media richness and media synchronicity theories, our paper distinguishes between online and offline networks for a student and theorizes about their different relationship with students’ course performance. We argued while there are many benefits (e.g., rehearsability) associated with online interactions, those benefits may not be realized. Drawing from media richness and media synchronicity theories, our paper explains why this could happen. Our findings supported our arguments. More specifically, the offline, more than online, network of a student was associated with students’ course performance, and the association became stronger when students also had high online centrality. Knowing the interdependence of and difference between online and offline networks makes us better understand how they affect students’ interactions and their course performance. Therefore, conceptualization of network structure at a more granular level (e.g., differentiating between online and offline networks) advances our understanding of how network structure is correlated with performance outcomes.

Third, this research extends our understanding of a specific structural property of the network, closeness centrality, by providing the theoretical rationale for why fast receipt of information relates to students’ course performance. A lucid understanding of various structural properties will be helpful when we need to differentiate one structural property from the other in theory development. For example, while degree centrality and closeness centrality both indicate access to large bases of information, closeness centrality also focuses on ease of access that creates speed of access to information.

Finally, our study has implications for system design, especially for e-learning collaborative systems used extensively in educational institutions. While prior research has discussed some important factors, such as ease of
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use and usefulness (Davis et al. 1989; Venkatesh 2000; Venkatesh and Davis 2000; Venkatesh et al. 2003) that affect technology adoption and use and suggested a system should be designed to increase users’ perception of ease of use and usefulness, this study underscores another important factor—fast receipt of information, that is likely to affect system effectiveness in facilitating students’ interactions. In a collaborative virtual environment, fast receipt of information is important in terms of clarifying misunderstandings between study partners or resolving problems that would otherwise affect study progress. In addition, our study has discussed the benefits of offline interactions that are missing in the online interactions. E-learning system designers should consider the possibility of capturing such missing elements in designing the e-learning system, e.g., capturing important contextual information during the online conversation, to enhance the effectiveness of the system.

Practical Implications

One of the major roles of educational institutions is to facilitate learning and improve students’ course performance. A viable approach to achieve such objectives is to facilitate effective collaborations among students, e.g., exchange of course information or provision of help in resolving course-related problems. Consistent with prior research, our study indicates social network affects collaborations among students, i.e., students who occupy central positions in the networks are likely to collaborate more effectively than those who occupy the peripheral position in the networks. Specifically, this study found that the extent to which individuals are proximal to others in the network was strongly correlated with their course performance. In view of this, schools should know about students’ network structure and help them develop structures such that they can receive timely assistance and/or feedback when needed. For example, schools can identify students who occupy the peripheral positions in the network and facilitate those students’ interactions with other students.

Our study indicates both online and offline communication transforms students’ communication networks. If students can occupy central positions in online and offline networks, the association between network centrality and course performance became the strongest and students are likely to perform better in this scenario. This suggests both online and offline communication is important. Schools should know about students’ existing online and offline networks and help them develop both networks. One approach that may help students develop their online network is to improve their knowledge of how to use different online communication technologies. If students do not have much knowledge of these technologies, they are less likely to use them or even when they use them, they may not be able to fully leverage the benefits of these technologies that may result in ineffective online communication. Ineffective online communication would have a negative impact on students’ interactions and thus prevent them from developing valuable network structures. Therefore, schools can provide training to students on how to use different online communication technologies. Moreover, schools should make students who rely solely on online communication realize the importance of offline communication and provide opportunity and support for them to communicate offline. For example, instructors can create team projects and require offline team meetings to facilitate offline interactions.

Limitations and Future Research

There are a few limitations that should be noted. First, although we emphasize fast receipt of information, we did not explicitly measure it because the extent to which individuals are proximal to others in the network is generally an equivalent index of speed of receiving information in the network. However, closeness centrality is conceptualized as ease of access to others that comprises 3 dimensions, i.e., access to larger quantity, higher quality and timely information. When closeness centrality is measured as a single composite score incorporating these 3 dimensions, we are not able to distinguish the individual effect of each dimension. Future research should develop measures for each dimension and compare the effect of each dimension on students’ course performance. Also, the two assumptions of closeness centrality have not been examined in current study due to resource constraints. Future research should explicitly test these assumptions.

Second, we only measured the communication network of the students. There could be other kinds of network that would affect students’ interactions and their course performance, such as the friendship and awareness networks. Friendship network indicates the strength of the relationship among students. Those who are close friends are more likely to offer timely assistance to each other. Awareness network provides information about who knows what. Without knowing other students’ expertise may result in accessing information that is not useful. Therefore, future studies should include other types of networks and compare their differential effects on students’ course
performance. In addition, future research should apply a more sophisticated approach (not only communication frequency) to collect network data. For example, future research can study specific type of communication, such as work-related advice or social support. Finally, although our study found significant correlation between network structure and course performance, it is perhaps premature to conclude a causal relationship between network structure and course performance because the relationship is not necessarily unidirectional. Future research should apply a longitudinal approach or a qualitative approach to gain better insights about the relationship between network structure and students’ course performance.

Conclusion

Our study contributes to the growing body of research in IS and education on how to facilitate students’ learning and enhance their course performance. We take a network approach and focus on the network structure to understand students’ interactions and their course performance. Drawing from media richness and media synchronicity theories, we distinguish students’ online and offline networks to theorize the relationship between network structure and students’ course performance. Also, this research develops a better understanding of a specific structural property of the network, i.e., closeness centrality. Our paper furthers social network theory by bringing insights from media richness and media synchronicity theories.

Acknowledgements

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