Social Network Characteristics of Learners in a Course Forum and Their Relationship to Learning Outcomes

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Keywords: Social Network Analysis, Network Structure, Network Position, Learning Outcomes.

Abstract: Recently, learning analytics has become the focus in the interdisciplinary field of education technology. Among learning analytical approaches, social network analysis (SNA) plays a critical role in examining collective learning patterns. In this study, we collect the forum data in an undergraduate course from a university's online learning system. On the one hand, SNA is adopted to investigate the learners' social network characteristics including network structure and network positions. On the other hand, we adopt the Pearson correlation analysis to identify the relationship between social network positions (e.g., degree centrality, closeness centrality, betweenness centrality, prestige and influence) and learning outcomes of learners. The experimental results show that most high-performing learners are located in the core position of network. Moreover, there is a significantly positive correlation between learner's social network centrality and learning outcomes, and high-performing learners have higher prestige and influence in the forum. The in-depth analyses could help teachers establish effective interactive mechanism that meets knowledge skills of different individuals, as well as guide learners to help each other in collaborative learning.

1 INTRODUCTION

In recent years, with the increasing fermentation of educational big data, learning analytics field has integrated various approaches from multi-fields such as information science, psychology, sociology, etc. Among these approaches, social network analysis have been a critical approach in exploring collective learning processes (Jo et al., 2014; Kellogg et al., 2014; Lee & Bonk, 2016). In online learning environment, learners often spontaneously form various self-organized learning communities based on their own learning requirements, interests or tasks. These communities are built based on the concept of social relations (Baker-Eveleth, 2003). Meanwhile, large scale of complex interactive data have been generated in various online learning systems or social media. The learners from an on-line learning community could naturally constitute a network, where each learner could be viewed as a node. Interactions among internal members con-tribute to knowledge construction of each individual in the network. Therefore, it is worth to investigate that, what are the structure of social networking and individual characteristics in interactions, and what is the relationship between characteristics of learners in the network and learning outcomes. The exploration of these questions is beneficial for reshaping education contexts, teaching methods and optimizing the learning effects of learners.

This paper aims to adopt social network analysis method to carry out the empirical research to reveal the structure and evolution trends of the social network of learners within online course forum, as well as the relationship between the network positions and the learning outcomes of learners. This paper is organized as follows. In Section 2, we review the definition of social network analysis and related research in the online learning environment. The design of this study is presented in Section 3. Results are showed in Section 4. Section 5 concludes findings in this study.

2 RELATED WORKS

Social network analysis (SNA) was derived from the studies of sociology, psychology and anthropology in

Liu, Z., Kang, L., Domanska, M., Liu, S., Sun, J. and Fang, C.
Social Network Characteristics of Learners in a Course Forum and Their Relationship to Learning Outcomes.
DOI: 10.5220/0006647600150021
In *Proceedings of the 10th International Conference on Computer Supported Education (CSEDU 2018)*, pages 15-21
ISBN: 978-989-758-291-2

the 1930s. Social network refers to a collection including social actors and various relations among them (Peter et al., 2011; Scott & John, 2000), in which relationship is the most important research object in SNA.

In the field of learning analytics, the main concerns are the relationship among learners, the relationship between learners and teachers, as well as the relationship between learners and learning resources. Learners often utilize social networks to find the most likely collaborative partner when they intend to seeking for helps to solve problems. A large number of studies have confirmed that SNA has important value in evaluating interactive behaviors of participants in the online learning environment. Laat et al. (2006) and Aviv et al. (2003) adopted SNA to solve a series of questions about calculation of participant activity degrees, network densities and identification of core participants. Karina et al. (2015) used SNA to evaluate the collaboration quality within collective online learning. Xu & Yang (2015) utilized social network metrics to characterize the strength of the relation-ship among learners, which was used to recommend learning companions for struggling learners in on-line course. Moreover, many researchers also investigated the relationship between social network characteristics and learning outcomes of learners. For instance, Dowell et al. (2015) and Tobarra et al. (2014) integrated SNA and discourse content analysis to jointly explore the associations among discourse features, learning outcomes and social centrality. Russo and Koesten (2005) suggested that learners' cognitive learning results could be predicted by analysing in-degree and out-degree indicators of individuals in learning networks. Rizzuto et al. (2009) demonstrated that network density could reflect learners' understanding levels on course materials to a large extent. The study of Lee & Bonk (2016) explored the relationship among learners in a blended learning environment by measuring the density, factions and centrality of a relationship net-work, and suggested that the active learners tend to be more popular within a relationship network.

3 EMPIRICAL RESEARCH

3.1 Research Questions

In the online learning environment, the forum interaction could help in knowledge sharing and learning supporting. To enable learners to effectively engage in knowledge construction in forums, there is a need to understand the network characteristics of learners and to demonstrate their relationship to learning outcomes. This study will be conducted aiming at the following questions:

(1) How does the social network structure of a course forum evolve as the course progresses?

(2) What is the relationship between social network positions of learners in a course forum and learning outcomes?

3.2 Research Objects and Dataset

The interaction data in this study comes from the forum of "Literature Translation" course, which was opened in the spring of 2014 in the online learning platform of a university. The teachers adopts the blending learning mode in this course, integrating the traditional classroom teaching and online collaborative discussions. The course lasts for 4 months. The learners who take it as an elective course are all senior undergraduate students majoring in English Translation. A total of 75 participants (74 students and 1 teacher) engage in discussions in the course forum. A total of 2982 posts were generated during their interactions. In order to explore the relationship between social network positions and learning outcomes in the course forum, we take the network characteristics of 75 participants as the independent variables including degree centrality, closeness centrality, betweenness centrality, prestige and influence. The learning outcome of each participant, as the dependent variable, is represented by his/her final overall score at the end of semester, which is composed of two parts, i.e., the usual score and the final score, each of which accounts for 50% of overall score.

3.3 Research Design

In order to address the first question, this study first investigates the evolution trends of learners' interactive frequency in the forum. In addition, we analyse the number of monthly posts by continuous participants and verify the difference of academic achievement between continuous participants and the entire population. Then, by SNA method, we construct the monthly and entire sociogram according to learners' interactions, and explore the network characteristics within monthly interaction and the overall network structure. As for the second question, the Spearman correlation analysis is used to demonstrate the relationship between social network positions of learners in a course forum and their learning outcomes.

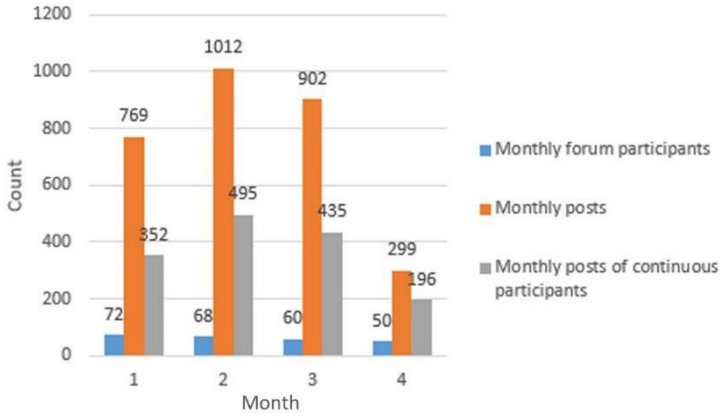

Figure 1: Statistical results of forum participants and posts.

Social network centrality embodies the central position of individual or organization in a network, indicating the importance of a member in the network. This study respectively utilizes degree centrality, closeness centrality and betweenness centrality to characterize each learner's social network position. Moreover, the learning network formed in forum interactions is actually a directed social network graph, which implies individual prestige and influence in interactions. Here, the individual prestige in the network is be quantified by in-degree centrality of the corresponding node, i.e., the number of replies an individual received. The individual influence is quantified by the out-degree centrality of corresponding node, i.e., the number of posts of an individual sending to other individuals (Shea et al., 2013). The tools used in this paper are Python's NetworkX Package and Gephi visual network analysis software, respectively.

4 RESEARCH RESULTS

4.1 Forum Participation

From Figure 1, we find that the number of monthly participants in forum tends to be a gradual descending trend in the teaching progress of the course. There are 72 participants in the first month, which decreases to 50 in last month. The monthly participation rate ranges from 66.67% to 96.00%. Compared with monthly participants, the number of posts ascend to 1,012 in the second month, but gradually descends in the last two months. When the course approaches the end of the semester, the average times of learners engaging in discussions will be significantly lower than before.

As for the continuous participants, who have been active (i.e., engaging in discussions each month) in forum during the entire course, there is a total of 43 learners to continually participate in the forum discussions, accounting for a half of the entire population. The statistical results indicate that the monthly posts of continuous participants show the same variation trend as the monthly posts of entire population.

4.2 Social Network Characteristics of Learners

4.2.1 Evolution of Network Structure

Figure 2 shows the sociograms of learners during four learning periods. In each diagram, green node denote teachers, orange node denotes the learners whose overall scores rank the top 20 in the class, purple node denotes the learners who participates in the forum and whose overall scores rank the last 20 in the class. Each node has a number (the teacher number is 0, student number is marked in the order of posting). The node size represents node's degree, which is the sum of replied and delivering postings). It can be seen from Figure 2 that the positions of the learners in the sociogram gradually vary with the course progresses. Nevertheless, the majority of the orange nodes are always at the core position of the network, which signifies that learners with better academic performance tend to be more active in the forum. In addition, in the first month, the green node has the largest degree and is located at the centre of the network, indicating that the discussions are mainly conducted between the teacher and learners. With the progress of the course, the teacher gradually moves to the edge of the sociogram, the forum interactions mainly occurs among learners.

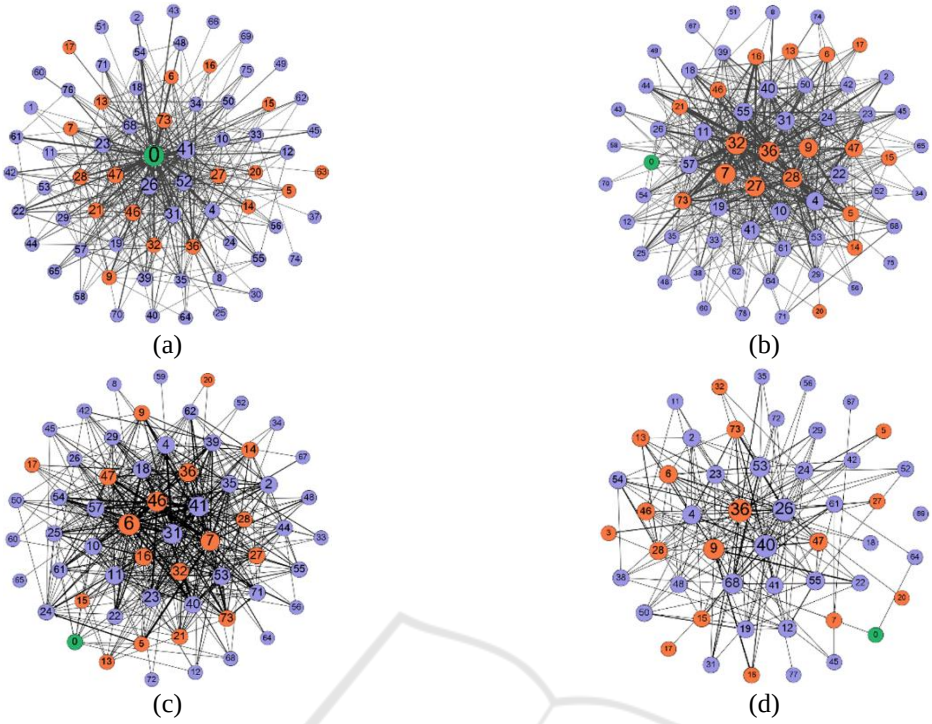

Figure 2: Monthly sociogram: (a) first month, (b) second month, (c) third month, (d) forth month.

When interactions among learners tend to be frequent, the sociogram gradually tends to be more intensive.

4.2.2 Characteristics of Network Structure

The results of network structure characteristics are shown in Table 1, it can be unfolded that network density, the average closeness centrality and betweenness centrality of the learners all show gradual rising trends. As the course approaches the end of semester, the interactions begin to gradually shrink, and the three indicators all exhibit a descending trend. Specifically, the overall network density of the course arrives at 0.45, which indicates that the network structure of the forum in this course is intensive. Moreover, the learners participating in the forum are relatively active and have close ties with each other. Figure 3 displays the overall network structure, the most orange nodes are located at the core position of the network, indicating that these high-performing participants actively participate in the forum discussions. An interesting phenomenon is that a small number of nodes such as 3, 17, 20 and 63 are located at the edge of the forum. Actually, in a blending teaching mode, although the four learners are rarely involved the forum, they may have the relatively good English foundation, and they could deeply engage in classroom learning. Therefore, they could also gain the higher overall scores.

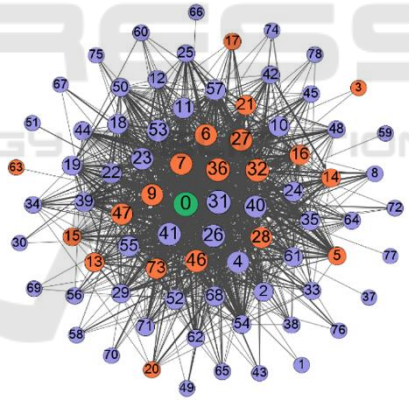

Figure 3: Overall sociogram.

4.3 Relationship between Learners' Network Positions and Learning Outcomes

4.3.1 Relationship between Network Centrality and Learning Outcomes

Degree centrality signifies the number of learners with who a learner establishes direct contacts in the forum. That is to say, the more times of interactions between a learner and other learners, the higher degree centrality of this learner. From Table 2, we can observe that the Spearman correlation coefficient

Table 1: Metrics of monthly and overall network characteristics.

Period	Max./min. out-degree	Max./min. in-degree	Degree (std.)	Density	Closeness centrality (std.)	Betweenness centrality (std.)
1st month	25/1	64/0	13.36 (±14.46)	0.19	0.30 (±0.04)	0.01 (±0.04)
2nd month	21/0	43/0	18.65 (±14.51)	0.28	0.32 (±0.08)	0.01 (±0.02)
3th month	21/0	43/0	18.63 (±13.47)	0.32	0.35 (±0.06)	0.02 (±0.02)
4th month	11/0	28/0	8.64 (±7.48)	0.18	0.21 (±0.08)	0.02 (±0.04)
Overall semester	42/0	65/0	34.71 (±26.43)	0.45	0.44 (±0.07)	0.01 (±0.02)

Table 2: Spearman correlation coefficient between social network centrality and learning outcomes.

Number of samples	Variable	Mean	Standard deviation	Degree centrality	Closeness centrality	Betweenness centrality	Overall score
N=74	Degree centrality	27.00	17.27	—			
	Closeness centrality	0.44	0.07	0.80**	—		
	Betweenness centrality	0.01	0.01	0.93**	0.79**	—	
	Overall score	87.81	2.30	0.46**	0.35**	0.39**	—

**p<0.01

Table 3: Spearman correlation coefficients between prestige, influence and learning outcomes.

Number of samples	Variable	Mean	Standard deviation	Prestige	Influence	Overall score
N=74	Prestige	33.47	46.02	—		
	Influence	35.22	26.09	0.67**	—	
	Overall score	87.81	2.30	0.41**	0.40**	—

**p<0.01

between individual degree centrality and learning outcome reaches 0.47 (p<0.01), indicating a highly positive correlation between the two variables in the network.

Closeness centrality indicates the average closeness degree between a learner and other learners in the forum, describing the degree of dependence of the learner to other learners in a network. The higher of closeness centrality of a learner, and the less he/she depends on other learners when seeking for helps. It can be seen from Table 2 that the correlation coefficient between the closeness centrality and learning outcome in this course reaches 0.35 (p <0.01), indicating that there is a significantly positive correlation between the two variables. This also implies that the close degree of a learner to others may predict his/her learning outcome to an extent.

Betweenness centrality represents the extent of a learner being an "intermediary" in interactions and describes the learner's ability to adjust the social interactions. The "intermediary" not only can control the direction and manner of an information flow, but also can coordinate relationship of any other two individuals or organizations. Therefore, the "intermediary" could play a bridge role in the learning network. It can be observed from Table 2 that the correlation coefficient between the two variables equals 0.39 (p<0.01), indicating a significantly positive correlation between the two variables. It can be assumed that, the higher the degree of "intermediary" role of a learners in the learning network, the higher his/her learning outcome. We also observe that, the betweenness centrality of learners is quite low, ranging from 0.00 to 0.07, while the teacher's betweenness centrality could reach the highest level of 0.11. This implies that the teacher actually plays a major leading role in coordinating interactive relationship within the forum, and guides learners to follow specific topics for enhancing the understanding of knowledge.

4.3.2 Relationship among Prestige, Influence and Learning Outcomes

In a directed social network, the in-degree centrality and out-degree centrality could be jointly used to indicate a learner's prestige and influence in the network (Shea et al., 2013). The in-degree centrality refers to the number of posts of a learner receiving from others. The high in-degree learner is considered

to have a high prestige in the network since the views and ideas expressed by prestigious learners are considered more important than other members. On the other hand, the out-degree centrality is used to measure learners' influence in a network, which can be measured by the number of posts of a learner delivering to others, indicating that the learner's activity degree in engaging in a forum. As shown in Table 3, there are significant positive correlations among learners' learning outcomes, prestige and influence. In other words, the learners with high academic performance tend to have a high prestige or influence. The influential learners typically could receive more replies. Additionally, the result also shows that the learners participating in interactions averagely gain the overall score of 87.81, and there is a quite low average deviation among the learners' scores (standard deviation is 2.3). As for those learners who never participated in the forum (a total of 5), their overall scores rank relatively backward such as 26, 27, 73, 74 and 77, respectively, the average score of which is less than learners who participated in the forum.

5 CONCLUSIONS

This study utilizes the social network analysis to investigate the evolution trends of network structure of learners within a course forum in a university' online learning platform, as well as further analyze the correlation between individual position features and learning outcomes in the forum. We could draw the following conclusions:

Social network structure of learners would dynamically vary as the progresses of course. In the first three months of the course, the network density, number of participants, number of posts and network centrality all show gradual upgrading trends. That is, the interactions among learners tend to be increasingly frequent while links among them become closer. However, in the last month, when the course approaches the end of the semester, both the numbers of participants and posts decrease, as well as the sociogram also becomes relatively sparse.

Within interactions of the course forum, the positions of learners in the network are partially correlated to learning outcomes. Social network centrality metrics have significantly positive correlations with learning outcomes. The learners with higher prestige or influence in social network could typically gain higher learning outcomes. And the factor that is most correlated to learning outcome is degree centrality, followed by betweenness centrality, the last one is closeness centrality. Finally, learner's prestige and influence in a forum are significantly positively correlated to their learning outcomes. This also indicates that the high-achieving learners generally have the high prestige and influence.

Therefore, if designed appropriately, discussion activities may not only enhance the interactions among learners, but also facilitate collaborative inquiry learning and knowledge construction among learners. To improve the activity levels of learners among interactions, teachers may design some high-quality interactive activities like inquiry-based discussions, questions and answers, literature reviews and knowledge brainstorms. Also, these activities should be designed to be appropriate for knowledge skills and interests of learners as well as have a certain difficulty to drive learners to actively conduct collaborative inquiries and discussions.

ACKNOWLEDGEMENTS

This work was supported by the Research Funds from National Natural Science Foundation of China (Grant No. 61702207), MOE (Ministry of Education in China) Project of Humanities and Social Sciences (Grant No. 16YJC880052), China Scholarship Council (Grant No. 201706775022), National Social Science Fund Project of China (Grant No. 14BGL131), Ministry of Education-China Mobile (Grant No. MCM20160401).

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