Mining Interactive Social Network for Recommending Appropriate Learning Partners in a Web-based Cooperative Learning Environment

Chih-Ming Chen
Graduate Institute of Library, Information and Archival Studies, National Chengchi University, Taipei 116, Taiwan, R.O.C.
chencm@nccu.edu.tw

Chin-Ming Hong
Graduate Institute of Applied Electronic Technology, National Taiwan Normal University, Taipei 106, Taiwan, R.O.C.
t07026@ntnu.edu.tw

Chia-Cheng Chang
Graduate Institute of Industrial Education, National Taiwan Normal University, Taipei 106, Taiwan, R.O.C.
hzotkimo@yahoo.com.tw

Abstract—**In Web-based cooperative learning environments, peer-to-peer interaction often suffers from the difficulty due to lack of exploring useful social interaction information, so that peers cannot find appropriate learning partners to make an effective cooperative learning. This problem easily results in poor learning outcomes in Web-based cooperative learning environments. Generally, learning partners assigned by instructors cannot ensure to compose suitable learning groups for individual learners in cooperative learning environments. Inappropriate learning partners not only easily lead to poor learning interaction and achievement, but also lose the meaning of cooperative learning. As a result, this study presents a novel scheme of mining social interactive networks for recommending appropriate learning partners for individual learners in a cooperative problem-based learning environment. The preliminary experimental results reveal that the proposed scheme provides likely benefits in terms of promoting learners' learning interaction and learning performance in cooperative learning environments.**

Keywords—**cooperative problem-based learning, social network analysis, learning partner recommendation**

I. INTRODUCTION

With the rapid development of the Internet and the popularization of World Wide Web, lots of people tend to transfer their social activities from real human interaction to virtual social network interaction. Most social network services are primarily web based and provide a collection of various ways for users to interact, such as chat, messaging, email, video, voice chat, file sharing, blogging, discussion groups, and so on [1]. In recent years, more and more studies paid attention to social network analyses [2-4] and many webs sites [5] provided social functionalities to benefit the learning interactions between learners. These social interaction mechanisms encourage a large amount of users to cooperatively participate in web learning activities. A social network is considered as a group of people, an organization or social individuals which are connected by social relations such as friendships, cooperative relations, or informative exchange [3]. Basically, the focuses of social network analysis lie on the analyzing patterns of relationships among people, organizations, states and such social individuals [2].

Cho *et al.* [6] indicated that theoretically there are abundant discussions emphasizing the value and the impact of social networks in the studies of organizational learning, knowledge management, and distance learning; however, few studies have actually examined the "origins" or "outcomes" of social networks in actual Computer-Supported Collaborative Learning (CSCL) or Cooperative Work (CSCW) settings. Furthermore, this study [6] also indicated social networks have significant impact on learning performance in a CSCL setting, since learning activities in such a collaborative environment are predominantly based on communication, social interactions, and coordination among distributed learners. Moreover, Tomsic and Suthers's study [7] investigated the social network structure of booking officers at the Honolulu Police Department and how the introduction of an online discussion tool affected knowledge about operation of a booking module. This study found that discussion tool provides benefit in terms of increasing knowledge in a cooperative discussing learning environment.

Although learners are grouped together for learning activities in cooperative learning environments, they often could not find appropriate learning partners to each other for conducting effective learning due to lack of complete social interaction information or they are assigned inappropriate learning partners by instructors. Therefore, this study presents a novel mining scheme of cooperative social networks to explore the active degrees and interactive relationships between learners in a cooperative problem-based learning environment. The exploring social information can be applied to enhance the learning interaction and performance in cooperative learning environments via revealing the social position ranking of individual learners and recommending appropriate learning partners.

II. EXPERIMENTAL ENVIRONMENT DESCRIPTION

This section explains the experimental environment for mining social networks. Figure 1 shows the system diagram of the employed cooperative problem-based learning system with mining social interactive network mechanism. The employed system is consisted of the cooperative problem-based learning system, social network analysis module and three databases. The cooperative problem-based learning system used in the study can provide a friendly learning environment, which is convenient to cooperatively solve a target problem assigned by instructors. All interaction information from learners' cooperative learning processes is stored in the learning record database. The social network analysis module aims to explore learners' social interaction relationships in the cooperative problem-based learning system based on the interaction information stored in the learning record database. Furthermore, the learning partner recommending agent can recommend appropriate learning partners for individual learners according to the results of mining learners' interaction relationships in the cooperative problem-based learning system.

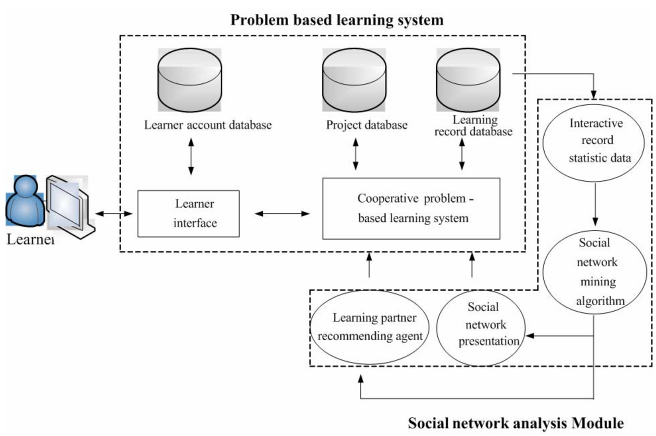

Figure 1. System diagram of the employed cooperative problem-based learning system with mining social interactive network mechanism

III. THE PROPOSED SCHEME OF MINING INTERACTIVE SOCIAL NETWORKS IN A COOPERATIVE PROBLEM-BASED LEARNING ENVIRONMENT

This section presents how the learners' interactive records stored in the learning record database can be used to explore social interaction relationships in the employed cooperative problem-based learning environment.

A. Social Networks in the Employed Cooperative Problem-based Learning Environment

Next, this study defines three interactive relationships between learners in the employed cooperative problem-based learning environment. Figure 2 illustrates an example to explain these three considered interactive relationships. In this example, we consider the interactive relationships of the learner A with the other three learning peers B, C, and D. The interaction initiated by the learner A to any peers is termed as "out-degree interaction". Similarly, the interaction initiated by any peers to the learner A is termed as "in-degree interaction". The bidirectional interaction with the learner A is termed as "linked interaction". Taking Fig. 2 as an example, the in-degree interaction value of the learner A is 2 because both the learners C and D initially interact with the learner A. The out-degree interaction value of the learner A is 2 because the learner A actively interacts with both the learners B and C. Moreover, the linked interaction value of the learner A is 1 because the learner A has bidirectional interaction with the learner C. The mathematical definitions for calculating three proposed interaction values are further explained in the following section.

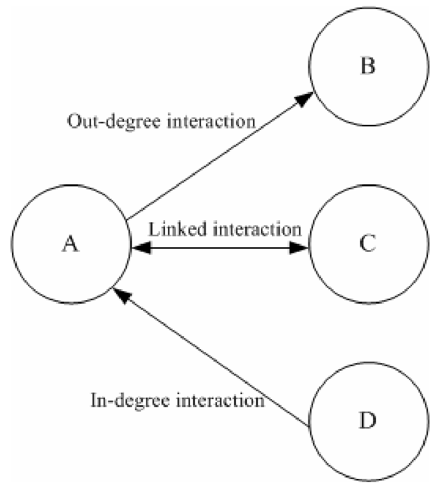

Figure 2. Interactive relationships between learners in the employed cooperative problem-based learning environment

B. Social Measures for Mining Interactive Social Networks in the Employed Problem-based Cooperative Learning Environment

This section mathematically defines five social measures for mining interactive social networks in the employed problem-based cooperative learning environment. They are detailed as follows:

(1) In-degree interaction value: The number of learners who actively interact with a certain learner in the cooperative problem-based learning environment. The in-degree interaction value can be formulated as

$$R_{In(n)} = \sum_{m=1}^{t} C_{m,n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where $R_{In(n)}$ stands for the in-degree interaction value of the n^{th} learner, $C_{m,n}$ is set to 1 if the m^{th} learner actively interacted with the n^{th} learner; otherwise, $C_{m,n}$ is set to 0, and t is the total number of learners excluding the n^{th} learner in the cooperative problem-based learning environment.

(2) Out-degree interaction value: The number of learners who accept interactive request from a certain learner in the cooperative problem-based learning environment. The out-degree interaction value can be formulated as

$$R_{Out(n)} = \sum_{m=1}^{t} C_{n,m} \text{ ....(2)}$$

where $R_{Out(n)}$ is the out-degree interaction value of the n^{th} learner, $C_{m,n}$ is set to 1 if the m^{th} learner accepts interactive request from the n^{th} learner; otherwise, $C_{m,n}$ is set to 0, and t is the total number of learners excluding the n^{th} learner in the cooperative problem-based learning environment.

The in-degree and out-degree interaction values represent popular and initiative degrees of a learner in the cooperative problem-based learning environment, respectively. Based on the in-degree and out-degree interaction values, this study further divides learners into four interactive types in the cooperative problem-based learning environment: Hub, Source, Sink and Island [2]. TABLE I illustrates the four interactive types based on interactive characters of individual learners in the cooperative problem-based learning environment.

TABLE I. FOUR INTERACTIVE TYPES BASED ON INTERACTIVE CHARACTERS IN THE COOPERATIVE PROBLEM-BASED LEARNING ENVIRONMENTS

Interactive type \ Interactive character	
Hub	Both in-degree and out-degree interaction values are high
Source	In-degree interaction value is low and out-degree interaction value is high
Sink	In-degree interaction value is high and out-degree interaction value is low
Island	Both in-degree and out-degree interaction values are low

(3) Linked interaction value : The number of learners who have bidirectional interaction with a certain learner in the cooperative problem-based learning environment. The linked interaction value can be formulated as

$$R_{Iv(n,m)} = \sum_{m=1}^{t} \left(C_{m,n} \times C_{n,m}\right) \text{....................(3)}$$

where $R_{Iv(m.n)}$ is the linked interaction value of the n^{th} learner with the m^{th} learner, $C_{m,n} \times C_{n,m}$ is equal to 1 if the bidirectional interaction exists between the n^{th} learner with the m^{th} learner; otherwise, $C_{m,n}$ is equal to 0, and t is the total number of learners excluding the n^{th} learner in the cooperative problem-based learning environment.

The linked interaction value represents the active degree of a learner in the cooperative problem-based learning environment. Next, this study uses the linked interaction value to compute the interactive score of each learner based on four defined interactive intervals in the cooperative problem-based learning environment.

(4) Interactive score: The interactive score is viewed as a weight score of interactive level between a learner with the other learning peers in the cooperative problem-based learning environment. According to quarter method of the statistics, this study divides all learners into four interactive intervals and assigns various weight scores for different interactive levels based on the linked interaction values of all learners. The Interactive score can be formulated as

$$I_n = \begin{cases} 4, R_{Iv} \geq R_{(\text{top 25\% high})} \\ 3, R_{(\text{top 50\% high})} \leq R_{Iv} \leq R_{(\text{top 25\% high})} \\ 2, R_{(\text{top 75\% high})} \leq R_{Iv} \leq R_{(\text{top 50\% high})} \\ 1, R_{Iv} \leq R_{(\text{top 75\% high})} \end{cases} \text{..........(4)}$$

where I_n is the interactive score of the n^{th} learner, $R_{(\text{top 25\% high})}$ is the interactive interval whose learners' linked interaction values are the top 25% high, $R_{(\text{top 50\% high})}$ is interactive interval whose learners' linked interaction values are the top 50% high, and $R_{(\text{top 75\% high})}$ is the interactive interval whose learners' linked interaction values are the top 75% high.

The learners categorized in the interactive intervals with high linked interaction value are easier to interact with peers than the learner categorized in the interactive intervals with low linked interaction value. Basically, these learners with high linked interaction value can be viewed as the Hub interactive type. On the other hand, the learners with low linked interaction value can be viewed as the Island interactive type. According to the interactive level, this study assigns various interactive score from 4 points to 1 point for further evaluating the social score of each learner in the cooperative problem-based learning environment.

(5) Social score : The social score represents the social position of a leaner in the cooperative problem-based learning environment. Suppose the n^{th} learner interacts with the m^{th} learner. The social score is formulated as

$$S_n = \sum_{m=1}^{t} \left(C_{m,n} \times C_{n,m} \times I_m\right) \text{.................(5)}$$

where S_n is the social score of the n^{th} learner in the cooperative problem-based learning environment, $C_{m,n} \times C_{n,m}$ is equal to 1 if the bidirectional interaction exists between the n^{th} learner with the m^{th} learner; otherwise, $C_{m,n} \times C_{n,m}$ is equal to 0, I_m is the interactive score of the m^{th} learner, and t is the total number of learners excluding the n^{th} learner in the cooperative problem-based learning environment.

Based on Eq. (5), when the n^{th} learner interacts with the m^{th} learner, the n^{th} learner can get the interactive score of the m^{th} learner, and the m^{th} learner can also get the interactive score of the n^{th} learner in the cooperative problem-based learning environment. Here, we further illustrate an example to explain how to compute social scores for individual learners in the employed cooperative problem-based learning environment.

Suppose that there are four learners A, B, C and D in the employed cooperative learning environment to perform problem-based learning. Figure 3 shows the interactive relationship graph of these four learners. Meanwhile, suppose the interactive scores of learners A, B, C and D are 3, 2, 4, and 1, respectively.

According to Eq. (5), the social score of the learn A is 2 because the learner A only exits the bidirectional interaction with the learner B. The social score of the learner B is 7 because the learner B simultaneously exists the bidirectional interactions with both the learners A and C. Similarly, the social scores of the learners C and D are 3 and 4, respectively. As a result, the ranking order of the social positions in this social network is B, D, C, and A. We can find that a learner may get lower social score than the others even he/she interacted with much more peers if he/she often interacted with peers who only have low interactive score. On the other hand, a learner may get higher interactive score than the others if he/she often interacted with peers who have high interactive score.

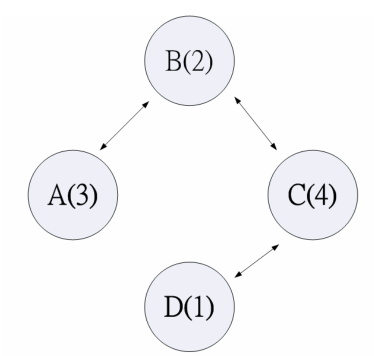

Figure 3. An example for illustrating how to compute social score in the employed cooperative problem-based learning environment (the number in the brackets represents the interactive score)

C. Cooperative Learning Partner Recommending Scheme based on the Results of Mining the Social Networks in the Employed Cooperative Problem-based Learning Environment

Many studies [6][7] had pointed out that the cooperative learning is an effective learning mode because it can promote learning interests and performance of learners via peer-to-peer interaction and assistance. However, how to find appropriate learning partners to further promote the learning performance of the cooperative learning is an essential research issue. Based on the observation mentioned-above, this study presents a cooperative learning partner recommending scheme based on the characters of individual learners in cooperative social learning networks. Basically, the learners who frequently interact with a certain learner are appropriate to be recommended to the learner as learning partners because they are familiar to each other. Furthermore, the learners who get a high social score are appropriate to be recommended to a certain learner as learning partners because they obtain high identification from most learners or they may be pleased or have excellent abilities to help the other peers to solve problems. Therefore, the study presents a cooperative learning partner recommending scheme based on a computed recommendation score which simultaneously considers two factors mentioned-above. The recommendation score for exploring appropriate learning partners can be formulated as

$$C_{n,m} = w \times \frac{S_m}{S_{\max}} + (1-w) \times \frac{R_{Iv(n,m)}}{R_{Iv(\max)}} \quad \text{……….(6)}$$

where $C_{n,m}$ represents the recommendation score of the m^{th} learner recommended to the n^{th} learner who would like to find appropriate learning partners in the cooperative problem-based learning environment, S_m is the social score of the m^{th} learner, $S_{\max}$ is the maximal social score among all learners, $R_{Iv(m.n)}$ is the linked interaction value between the n^{th} learner and the m^{th} learner, $R_{Iv(\max)}$ is the maximal linked interaction score among the learners who interacted with the n^{th} learner, and w is a adjustable linear combination weight.

IV. EXPERIMENTAL ANALYSIS

This section presents our experimental analyses. In our experiments, 34 learners of Nation Hualien University of Education who were studying in the Department of Chinese Language and Literature were invited to participate in cooperative learning in the employed cooperative problem-based learning system with mining social interactive network mechanism. These learners were assigned a target problem related to "how to design a teaching plan for computer integrated instruction". Meanwhile, they must perform cooperative learning with peers to finish the problem-based learning processes in order to plan a teaching plan for the course of the computer integrated instruction during four weeks. These 34 learners generated a lot of social interaction records and these interaction records were stored in the learning record database. This study adopted these social interaction records to explore their social interaction networks. Figure 4 reveals the partial social position ranking of learners explored by the proposed scheme of mining interactive social networks in the cooperative problem-based learning environment. We found that instructor is the most active person in the interactive social networks because she often encouraged learners through sending messages during learning processes. In addition, learners also often sent messages to the instructor to ask assistance. If a learner would like to know his/her interactive relationships with the other peers, he/she only needs to click the personal icon and the system will present the corresponding interactive relationship diagram for him/her. Figure 5 displays the interactive relationship diagram of the number 72 learner with five learning peers in the cooperative problem-based social learning networks. Figure 5 reveals that the in-degree interaction value, out-degree interaction value, linked interaction value, interactive score, social score, and social position of the number 72 learner are 7, 19, 5, 4, 14, 4, respectively.

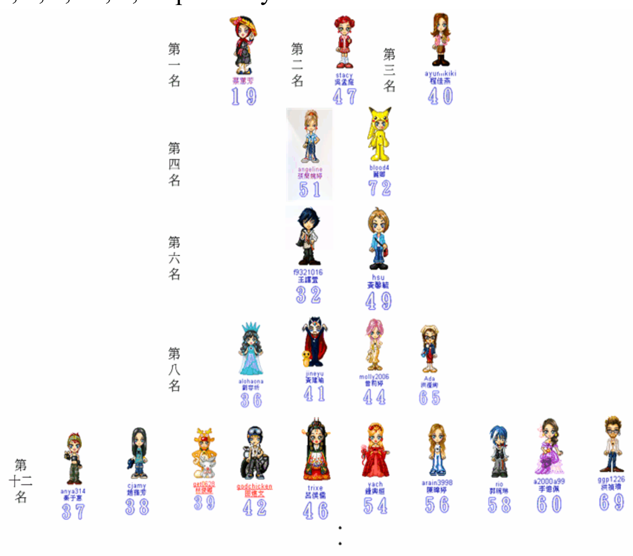

Figure 4. Illustration of a partial social position ranking in the employed cooperative problem-based learning environment

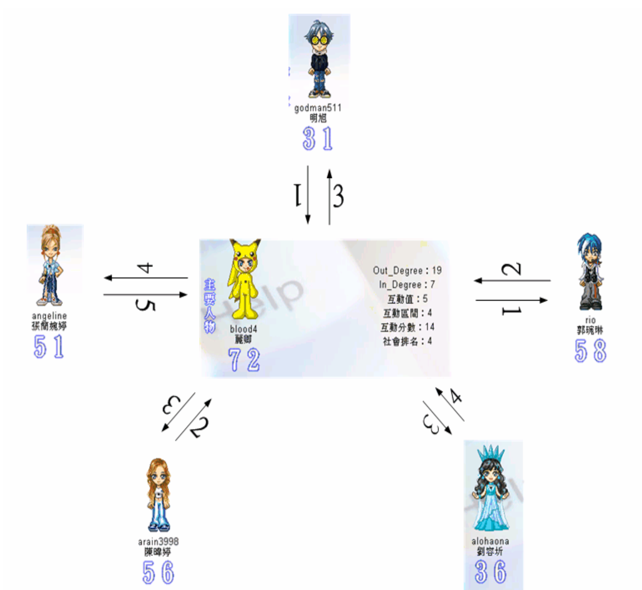

Figure 5. The interactive information of the number 72 learner in the employed cooperative problem-based learning environment

TABLE II illustrates the interactive information of instructor and three selected learners with various active levels in the cooperative problem-based learning environment. We found that the most active learner, moderate active learner, and most inactive learner are the number 47, 33, and 79 learners, respectively. Therefore, the number 47 learner can be viewed as the Hub type learner, and the number 79 learner can be viewed as the Island type learner. Based on the social information, instructor should encourage the number 79 learner to interact with the other peers in the cooperative problem-based learning environment.

Additionally, the proposed system can recommend those learners who had successfully passed current learning stage in the target problem assigned by instructor as the learning partners for those learners who still had not passed the current learning stage in the target problem. This is because these learners who had successfully passed current learning stage in the target problem can help those learners who still had not passed current learning stage in the target problem to solve learning problems.

TABLE II. INTERACTIVE INFORMATION OF INSTRUCTOR AND THREE SELECTED LEARNERS WITH VARIOUS ACTIVE DEGREES IN THE COOPERATIVE PROBLEM-BASED LEARNING ENVIRONMENT

Comparison Item \ Role	Instructor	Number 47 learner	Number 33 learner	Number 79 learner
Out-degree interaction value	49	7	4	0
In-degree interaction value	18	8	3	0
Linked interaction value	17	9	2	0
Interactive score	4	4	2	1
Social score	44	20	6	0
Social position ranking based on social score	1	2	22	34

TABLE III displays the interactive scores of the number 72 learner with five different learners who have bidirectional interaction with the number 72 learner. TABLE IV shows the comparison of recommended learning partners for the number 72 learner under considering different linear combination weights. We found that the most appropriate learning partner for the number 72 learner is the number 51 learner when the adjustable linear combination weight w is set to 0.1 and 0.5. Actually, the number 51 learner has the highest linked interaction with the number 72 learner. On the other hand, we also found that the most appropriate learning partner for the number 72 learner is the number 47 learner when the adjustable linear combination weight w is set to 0.9. The social position of the number 47 learner is 2. In sum, setting a low linear combination weight tends towards recommending the learning partners who have high interaction relationship with the learner. By contrast, setting a high linear combination weight tends towards recommending the learning partners who have high social position in the cooperative problem-based learning environment.

This study also found that most learners prefer to be recommended the learning partners who have high linked interaction relationship with oneself. Probably, most learners are used to perform cooperative learning with familiar learners. From the point of view of learning, recommending the learning partners who have excellent personal characters or abilities is also a critical consideration. Therefore, how to determine an optimal linear combination weight for recommending appropriate learning partners has been considered as an urgent research issue in our future study.

V. CONCLUSION

This study proposes a novel scheme for mining social networks in an employed cooperative problem-based learning environment. In addition, this study also applies the results of mining social networks to present a learning partner recommendation scheme for recommending appropriate learning partners for individual learners. The preliminary experimental results show that exploring social positions of individual learners in the employed cooperative problem-based learning environment has high potential to encourage learners to interact with peers more actively. Moreover, recommending appropriate learning partners for individual learners provides likely benefit in terms of promoting the learning performance of individual learners in cooperative problem-based learning environments. In the future, the proposed scheme will be applied to real teaching scene to further demonstrate these two advantages mentioned-above.

TABLE III. THE INTERACTIVE SCORES OF THE NUMBER 72 LEARNER WITH FIVE DIFFERENT LEARNERS WHO HAVE BIDIRECTIONAL INTERACTION WITH THE NUMBER 72 LEARNER

	Number 31 learner	Number 36 learner	Number 51 learner	Number 56 learner	Number 58 learner
Number 72 learner	1	3	4	2	1

TABLE IV. COMPARISON OF RECOMMENDED LEARNING PARTNERS FOR THE NUMBER 72 LEARNER UNDER CONSIDERING DIFFERENT WEIGHTS

Adjustable weight / Recommending order	$w = 0.9$	$w = 0.5$	$w = 0.1$
The recommended learner with first priority	Number 47 learner (0.9)	Number 51 learner (0.85)	Number 51 learner (0.97)
The recommended learner with second priority	Number 51 learner (0.73)	Number 47 learner (0.5)	Number 56 learner (0.49)
The recommended learner with third priority	Number 40 learner (0.72)	Number 56 learner (0.45)	Number 58 learner (0.265)

REFERENCES

[1] Wikipedia: social network service, web avialable at http://en.wikipedia.org/wiki/Social_network_service

[2] Jamali M. and Abolhassan H., " Different aspects of social network analysis," IEEE/WIC/ACM International Conference on Web Intelligence, pp. 66-72, 2006.

[3] Wasserman S. and Faust K, *Social network analysis: Methods and applications*. Cambridge University Press, 1994.

[4] Freeman L., *Graphic techniques for exploring social network data*. New York: Cambridge University Press, 2005.

[5] Social Network in Education, web available at http://socialnetworksined.wikispaces.com/

[6] Cho Hichang, Gay Geri, Davidson Barry & Ingraffea Anthony, "Social networks, communication styles, and learning performance in a CSCL community," *Computers & Education*, vol. 49, issue: 2, pp. 309-329, 2007.

[7] Tomsic Astrid and Suthers Daniel D., "Discussion tool effects on collaborative learning and social network structure," *Educational Technology & Society*, vol. 9, no. 4, pp. 63-77, 2006.