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Collaboration Levels in Asynchronous Discussion Forums: a Social Network Analysis Approach

Cecilia Luhrs & Lewis McAnally-Salas
Autonomous University of Baja California, Mexico

Abstract

Computer Supported Collaborative Learning literature relates high levels of collaboration to enhanced learning outcomes. However, an agreement on what is considered a high level of collaboration is unclear, especially if a qualitative approach is taken. This study describes how methods of Social Network Analysis were used to design a collaboration index. The study was conducted in a heterogeneous context of hybrid and online courses, in a virtual classrooms system, in higher education. Results show that the collaboration index effectively identified levels of collaboration in asynchronous discussion forums.

Collaborative work has been viewed as a necessity by educational literature in recent times. It is believed that a pedagogy based on communities facilitates learning. The theoretical basis of this pedagogical principles date back to the socio-constructivist ideas of Vigotsky and Piaget for whom social interaction was a critical component of learning processes (Dawson, 2008).

In Computer Supported Collaborative Learning (CSCL) contexts, and especially in asynchronous discussion forums, socio-constructivist principles are relevant because, individual learning occurs in a social context. These principles guide the design and development of online learning environments that incorporate elements as self-reflection, authentic learning, active learning, and collaborative learning (Gibson, 2013). However, despite the growing number of computer mediated learning programs, several educational studies indicate that the theoretical and methodological body of knowledge that explains how we learn with technological support is still scarce and fragmented (García Cabrero, Márquez Ramírez, Bustos Sánchez, Miranda Díaz, & Espíndola, 2008).

Several studies have investigated the effectiveness of various educational technologies to improve student interaction, motivation, and academic performance in technology mediated courses but there is still a need for studies that analyze how relations and networks develop in education contexts (Dawson, 2008). Asynchronous discussion forums are one of the most useful technological resources for students to interact in hybrid and distance courses. To make the best use of these forums it is particularly relevant to understand the dynamics of interaction and collaboration among the participants in the forums and the factors influencing them.

There are many unsolved questions about the mechanisms and nuances of interaction and collaboration in computer mediated communication. Many teachers have a clear understanding of the importance of collaboration but face the challenge to motivate their students to participate in online discussions, especially when they lack formal or proper training as discussion forum moderators. Participants in computer-mediated courses also intuitively deduce that acquiring knowledge is more than having access to information. They perceive there is a much wider and complex connection between interaction and knowledge construction (Salmon, 2000).

Social Network Analysis (SNA) programs have a great potential to explore interaction and collaboration in asynchronous discussion forums because the discussion logs can be easily transformed into networks that provide a visual representation of the interaction patterns in the forums. Reffay and Chanier (2003) mention that "Systems developed to support collaboration during the learning process need to rely on the basic data, which often are textual data, coming from communication tools". SNA programs generate more than graphs, they provide statistical data like the number of participants in a forum, the number of exchanged messages, and several other values that can be used as indicators of interaction, connectivity and collaboration. It is especially necessary to have Distance Learning Management Systems (DLMS) capable of calculating and showing the structure of students' groups and the cohesion among them to address possible learning issues before they become irreversible (Reffay & Chanier, 2003).

This article presents a study that used SNA statistical values to create a collaboration index (CI) which assigns a numerical value to levels of collaboration in asynchronous discussion forums. The CI is applied to effectively identify forums of interest in a very heterogeneous CSCL context.

Literature Review

Constructivism is the most common pedagogical approach for online learning. The central constructivist idea is that the teacher does not transmit or impose meaning. Students create meaning from learning activities chosen by the teacher. Meaning is personal and it depends on what is previously known, the way that knowledge is used and the motives and intentions of the learner. Learning changes the way of seeing and understanding the world and its phenomena (Biggs, 2006).

Social constructivism draws on the ideas of constructivism and becomes a model that states that knowledge is not only acquired from the relation of the subject with his environment but the social environment is incorporated as a factor to this equation. Thus the new knowledge emerges from schemes that result from a person's reality and the comparison that person makes with the schemes of the people with whom he interacts (Parica, Bruno, & Abancín, 2005; Payer, 2005).

Collaborative learning is one of the central tenets of social constructivism and states that collaboration promotes learning because it allows students to take the initiative, develop their creativity, critical thinking, and dialogue level (Palloff & Prat, 2007). Computer Supported Collaborative Learning (CSCL) is an emerging branch of collaborative learning. Its main interest is how students learn in collaboration with others with the help of the computer (Stahl, Koschmann, & Suthers, 2006).

It is believed that the use of CSCL, under a constructivist approach, allows the use of information and communications technologies to address one of the most common problems in educational systems: passive students who only absorb information from the teacher, without critical reflection of the contents. The reason higher education emphasizes the use of CSCL is

because it encourages active use of thought, and challenges the students to use advanced mental abilities through learning (Veldhuis-Diermanse & Wageningen Universiteit, 2002).

In computer supported collaborative learning contexts (CSCL), asynchronous discussion forums are recognized as a key element for communication and collaborative learning. Asynchronous discussion forums can be defined as technological resources that enable members of a group to interact in different times and locations to explore topics and discuss ideas from different perspectives through messages that remain as logs and can be complemented.

Asynchronous discussion forums enable the exchange of ideas to discuss a topic related to the course objectives. This pedagogical method offers many possibilities for learning. Participants not only have experiences that go beyond the physical context of the classroom but they acquire a new perspective and have more time to think about issues under discussion. Participants in the forum relate new learning to previous experiences and build knowledge as they collaborate and become involved in social negotiation (Abawajy, 2012).

Asynchronous discussions conducted in forums are activities of dialogic nature. By interacting, participants become part of a virtual community. The nature of content emerges via the interaction among students, students and the teacher or other sources of knowledge (U.S. Department of Education, 2010). Numerous investigations point to interaction and collaboration as key elements for quality online education, capable of improving the learning outcomes and student satisfaction.

Terry Anderson published *The Equivalency Theorem* in 2003 to explain the mechanisms of interaction in distance education. This theorem also explains the differences between strategies and activities oriented to independent learning and those oriented to collaborative learning. From The Equivalence Theorem, Miyazoe & Anderson (2010) developed the Interaction Equivalency Theorem which can be summarized in two theses:

1. It is possible to achieve a deep and meaningful learning experience as long as one of the three forms of interaction (student-teacher, student-student, student-content) is at a high level. The other two may be offered at minimal levels or even eliminated without lessening the educational experience.
2. High levels of more than one of the above forms of interaction could result in a more rewarding educational experience but it may not have the same cost (or time)-benefit than less interactive learning sequences.

The first thesis addresses the quality of interaction and states that high levels of one form of interaction ensure the quality of learning. That is, a student can achieve a quality learning experience by interacting intensively with his peers even if the instructor was unavailable or the course contents were not appropriate. The second thesis refers to the quantity of interaction. The quality of learning of a course with high levels of the three types of interaction would be high but the time investment required from students and teacher would make it expensive and unsustainable (Miyazoe & Anderson, 2010).

The Interaction Equivalency Theorem has a strong theoretical foundation and reveals the importance of interaction in a CSCL context. We believe, as Balaji and Chakrabarti (2010) that interaction promotes productive relations to collaboratively explore topics of the class and that it is closely related to the level of connectivity among the participants in the discussion forums. Connectivity and interaction can be explored using methods of Social Network Analysis.

Social Network Analysis (SNA) can be defined as "the application and network theory to the modeling and analysis of social systems. It combines the tools for analyzing social relations and a theory for explaining the structures that emerge from the social interactions" (Complexity

Learning, 2014). SNA investigates resource exchanges among social actors represented in the form of nodes and the ways their interactions, represented in the form of links, allow the formation of social ties within a social system (Dawson, 2008). A social network is composed of a group of individuals who interact to share and discuss specific information; in the process they form a specialized social network. Formation of groups is a central issue in online collaborative learning, the actions of each participant modify the structure of the network (Reffay & Chanier, 2003) and they hold together as they try to reach specific learning outcomes. The network contains information and it is maintained by the members' information exchanges. Sociologists suggest that "computer networks are social networks that link institutions, people, and knowledge" (Zhu, 2006).

In 1997, Garton, Haythornthwaite, and Wellman demonstrated that computer-mediated communications could be visualized as social networks and that in those networks it is possible to identify patterns of interaction. In CSCL contexts, methods of social network analysis can be used to evaluate the social structures and processes. The results of those evaluations can be taken as a reference for deeper analyses of knowledge construction (Dawson, 2008).

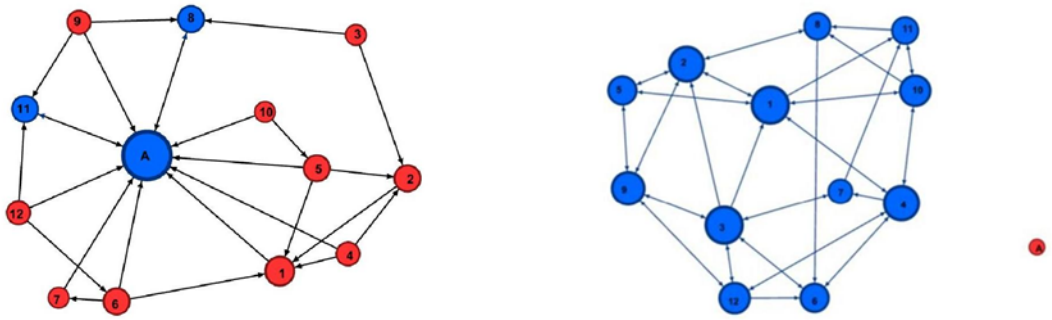
One way to better understand and assess if participants' postings are prompting responses from others is to visualize their interaction patterns in social network diagrams (Swan, Shen, & Hiltz, 2006).

In Search for a Collaboration Index

Interaction in CSCL is a general concept. It comprises the three types of interaction stated in the Interaction Equivalency Theorem, although it goes beyond that. Balaji & Chakrabarti (2010), say that interaction is also closely related to the level of connectivity among the participants. If there are different levels of interaction and connectivity in social networks it can be assumed that there are also different levels of collaboration among the members of a network.

Collaborative learning theories state that knowledge is socially constructed and that adequate collaboration results in the acquisition of deeper and more complex knowledge and higher cognitive skills (Lehtinen, Hakkarainen, Lipponen, Rahikainen, & Muukkonen, 1999). Collaborative learning theories and the possibilities SNA offers to explore interactions among the participants in asynchronous discussion forums guided our search for a collaboration index.

We took interaction and connectivity as the basis of the collaboration index. Interaction is understood as the centralization value in each forum, this is, how evenly distributed are the messages among the participants. Connectivity is understood as the network's strongly connected components, this is, the percent of the participants in the forum who have the possibility to access shared information.



Forum 1
Centralization = 0.7879
SCC= 0.2308
CI = 0.0490

Forum 2
Centralization = 0.3333
SCC= 0.9231
CI = 0.6154

Figure 1. Forums 1 and 2 illustrate how interaction can be understood as a network's centralization value and connectivity can be understood as a network's strongly connected components.

To understand the concept of centralization it is necessary to first understand what centrality means.

Centrality. Figure 1 shows the networks of two different discussion forums. There are 13 participants in each network. Participants are represented as nodes which grow in size according to the number of messages they send and receive. The exchanged messages appear as arrows or links.

Centrality scores indicate how well positoned is a participant in the network to receive and disseminate information to other members of the network. The degree of centrality equals the number of links each of the network's members has (Dawson, 2008).

Centralization

The value of centralization tells "how much variation there is in the centrality scores among the nodes" (Adamic, n.d.). The formula to calculate a network's centralization value is the same as that used to obtain a standard deviation. That is, the value represents how far away are each of the values of centrality from the largest centrality value in the network.

Forum 1 has a centralization value of 0.79. It can be seen that one of the nodes (A) is centralizing the discussion. The centralization value for Forum 2 is 0.33. The centralization value decreases as interaction in the network is more evenly distributed. Interaction, represented as the centralization value of a network, is the first component of the collaboration index.

The second component of the collaboration index is connectivity and it is represented as the value of the strongly connected componets in a network.

Forums 1 and 2 also illustrate how connectivity among the members of a network can be respresented as the value of the strongly connected components (SCC) of a network. But first, it is necessary to explain what a SCC is.

Strongly Connected Components

In a strongly connected component "each node within the component can be reached from every other node in the component by following directed links" (Adamic, 2008). In Forum 1, blue nodes A, 8, and 11 form a SCC. Following the arrows each of the nodes can reach each other. This does not happen with the rest of the nodes. SCC values range from 0 to 1 and can be understood as a percent. The SCC value for the network in Forum 1 is 0.2308, or it could be said that 23.08% of its members have the possibility to access the information they share directly or through other members of the component.

An SCC value of 0 means there are not strongly connected members in the network, they are not answering each other's questions or exchanging ideas, they are not engaged in collaborative learning. The SCC value for Forum 2 is 0.9231, this is 92.31% of the network's members (blue nodes) are strongly connected. In other words, the higher the SCC value the more connected are the members of the network.

Collaboration Index

From the above two premises can be devised:

Premise A. The lower the centralization value, the more evenly distributed is the participants' interaction in the forum. It could be said that collaborative learning is favored when interaction is more distributed among the members of a social network because more members contribute ideas to explore a topic or solutions to solve a problem.

Premise B. The higher the SCC value, the closer the connectivity among the members of a network. It could be said that high levels of connectivity among the members of a network offer better chances to reach learning objectives in a computer supported collaborative learning context.

Based on premises A and B, we propose a collaboration index (CI) to identify different levels of collaboration in social networks.

The Collaboration Index (CI) can be calculated with the following formula:

$$CI = (1-C)(SCC) \text{ where}$$

C= Centralization value of the network
SCC= Strongly Connected Components value of the network.

Applying the formula to the networks of Forums 1 and 2 we obtain a collaboration index (CI) of 0.05 for Forum 1 and a CI of 0.62 for Forum 2. This means that participants in Forum 2 are working more collaboratively than participants in Forum 1 to reach the learning objectives of the asynchronous discussion forum.

It is important to mention two things. First, that without SCC the CI index equals 0. And second that centralization values can be greater than 1, in this case the CI index results in a negative number. Negative numbers indicate extremely centralized, star shaped, networks.

The Interaction Equivalency Theorem (Miyazoe & Anderson, 2010) states that high levels of student-student, student-teacher, or student-content interaction result in deep and meaningful learning. Still if we intend to adhere to the theoretical foundations of CSCL to achieve deep learning then, interaction levels should not only be high, but evenly distributed among the members. Amhag & Jakobsson (2009) carried out a study about collaborative learning viewed as a collective competence. Their results indicate that enhanced and deeper learning

occurs "when different understandings, significances, and contradictions in course assignments are made visible and explicit to the participants". High values of the CI index mean that most of the members of a network are enriching the discussion with their exchange of ideas, points of view, and personal experiences. That is what collaborative learning is about.

Networks in Figure 1 show student-teacher type of interactions. Nodes labeled "A" in both networks represent the teacher. In Forum 1, the teacher interacts heavily with the students and is at the center of the discussion. In Forum 2, the teacher does not intervene in the discussion, he is a "guide on the side" (Collison, Elbaum, Haavind, & Tinker, 2000). By observing the networks we cannot say that deep learning is happening in one of the networks and not in the other. That would require a deeper analysis, perhaps a content analysis of the messages posted on the forums. But the CI for both networks informs that participants in Forum 2 are collaborating more than participants in Forum 1.

In networks with few students like those represented in Figure 1, it is easy to observe if interaction is centralized in one or more participants and to notice imbalances in collaboration. It is also easy to see if the members of the network are or not strongly connected. However, in larger networks a visual analysis may not be enough. Figure 2 shows two different asynchronous discussion forums, each with 28 participants. It shows close values of SCC (nodes in blue), but it is difficult to visually assess in which network participants are collaborating more.

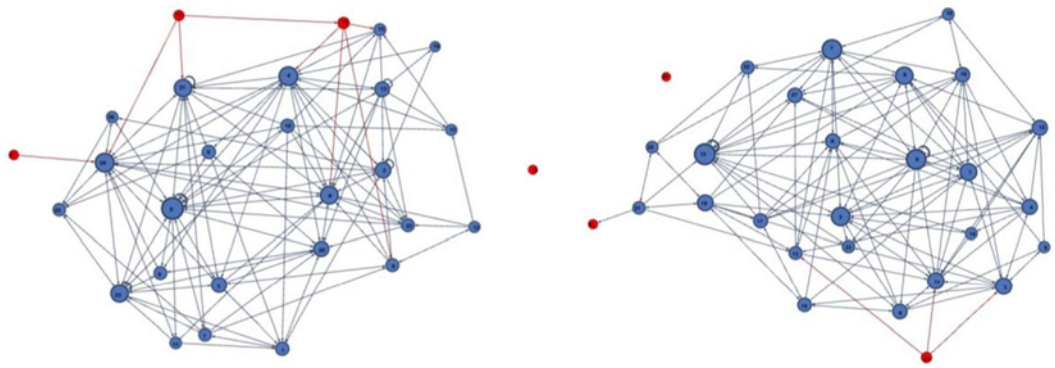


Figure 2. Forums 3 and 4 illustrate the difficulty to visually assess collaboration in larger networks and the effectivity of the collaboration index to identify levels of collaboration.

However, if we calculate the CI for both networks, differences in collaboration are revealed. The closest the collaboration index is to 1, the more evenly the participants in the forum are interacting and the more strongly connected they are connected. This could be especially useful to monitor or assess collaboration in discussion forums with large numbers of participants like those in Massive Open Online Courses (MOOCs).

If there was a need to assess the levels of collaboration of only student-student type of interaction, SNA programs like the ones used for this study make it possible to remove the teacher's node and its related links. The CI index could then be calculated for the new network leaving out the influence of the teacher. Reffay and Chanier (2003) proposed something similar,

removing the teacher's node to create a subgroup of what they called cohesion and we understand as the centralization value of the network.

Context of the Investigation

This research was carried out at a public university in Mexico in the @ulas-UABC System, a virtual classroom system, embedded in the Moodle platform, an open source Learning Management System. This technological resource was open for all UABC teachers and its use was optional. One hundred forty-five teachers opened a total of 347 courses in the @ulas-UABC System from March 1, 2007 to December 19, 2013. The teachers designed their courses based on their knowledge and desired outcomes for hybrid or online courses. Most of the courses used forums for notices and announcements, social interactions, or other non-task related purposes. Only 32 courses, belonging to the schools of engineering, education, health, language teaching, and psychology used asynchronous discussion forums for academic interactions. There were 132 asynchronous discussion forums in those 32 courses.

The 132 forums, base of this analysis, were divided in two delivery types: 70 were part of hybrid courses and 62 were part of online courses. The forums were used in four levels of instruction: 85 in undergraduate courses, 21 forums in graduate courses, 19 forums in Ph.D. programs and 7 in Professional Advancement Training (PAT) courses. Forums in the first three levels lasted 12 weeks. One of the PAT courses lasted 16 weeks and the other 4 weeks. Seventeen teachers moderated the 132 discussion forums and 1,910 students participated in them. Teachers had not received formal training as asynchronous discussion forums moderators.

Table 1.

Overview of the virtual classrooms system @ulas-UABC

Total of courses in @ulas-UABC		347
Total of teachers who taught in @ulas-UABC		145
Number of courses with academic type forums		**32**
Number of teachers who taught the 32 courses		**17**
Number of forums in the 32 courses		**132**
Number of students in the 132 forums		1910
Two delivery types:		
Hybrid forums	70	
Online forums	62	
Four levels of instruction:		
Undergraduate forums	85	
Graduate forums	21	
PhD forums	19	
Professional Advancement Training forums	7	

Objectives of the Study

1. To extract identification data of the courses and descriptive elements of the forums that used asynchronous discussion forums with academic purposes in the @ulas-UABC system in order to characterize the context of the forums.
2. To generate the SNA graphs for the 132 asynchronous discussion forums.
3. To calculate the collaboration index (CI) and identify the forums with the highest level of CI for each of the 17 teachers who used forums with academic purposes in the @ulas-UABC system.
4. To determine possible associations between the CI and other identification elements of the courses and descriptive elements of the forums.

Methodology

1. Three hundred forty-seven courses in the @ulas-UABC System from March 1, 2007 to December 19, 2013 were revised and courses that used discussion forums with academic purposes were selected. Identification data of the courses and descriptive elements of the forums were extracted.
2. To generate the SNA graphs for the 132 asynchronous discussion forums it was necessary to extract the forums' codes from Moodle. This was done using the free download software program Social Networks Adapting Pedagogical Practice (SNAPP). This program is a discussion mapping tool for platforms like Moodle, Blackboard, and Desire2Learn. SNAPP generates a visual representation of student-student, teacher-student interactions in the forums and node size and links thickness indicate the frequency of the messages (Aneesha, 2011; Elhassan, 2011). We decided to use SNAPP just for the extraction of the codes and use a more sophisticated SNA program to generate the discussion forums graphs.

   The codes generated with SNAPP were imported into another SNA program, Gephi. This program is a free and open-source interactive platform capable of generating all kinds of networks and dynamic graphs (The Gephi Consortium, 2015). Gephi provided two statistical values necessary to calculate the collaboration index (a) Centrality scores, needed to calculate the centralization values for each forum using Freeman's general formula for centralization (Adamic, n.d.) and (b) Values of the strongly connected components, in each network. All networks shown in this article were created with Gephi.
3. With the centralization and SCC values of the 132 discussion forums, the collaboration index was calculated. The highest collaboration index obtained by each of the 17 teachers was identified.
4. The CI scores for the 132 discussion forums were analyzed to look for possible associations with a) Identification elements of the forums: delivery type (hybrid or online), if the participation in the forums was mandatory or not, and the educational level of the course and b) Descriptive elements of the forums: topics and responses for students and teachers, number of participants in the forums, and the average responses per student in the forums.

Results

1. In the 347 courses in the @ulas-UABC System that were opened from March 1, 2007 to December 19, 2013, 32 courses that used asynchronous discussion forums for academic interactions were identified. These courses belonged to the Schools of Engineering, Education, Health, Language Teaching, and Psychology. There were 132 asynchronous discussion forums in those 32 courses. Table 2 shows the identification data of the courses and descriptive elements of the forums.

Table 2.
Courses' identification and forums descriptive elements

Identification data	*Course* = name of the course that the forum belongs to. *Teacher* = initials of the teacher. *Delivery type*= delivery type of the course (hybrid or online). *Assessment* = mandatory participation in the forum (1 = yes, 0 = no)**.** *Level* = educational level of the course (Ph.D. degree, master's degree, bachelor's degree, professional advancement training).
Descriptive data	*Total topics* = topics of the teacher and/or students that generate a response or sequence of responses. *Teacher Topics* = topics posted by the teacher. *Student Topics* = topics posted by the students. *Total Responses* = Responses given to a topic started by the teacher or by the students. *Teacher Responses* = responses of the teacher. *Students Responses* = responses of the students. *Total Participants* =number of participants in the forum, including the teacher. *Participant Students* = number of students participating in the forum.
Compound descriptive data	Teacher Topics + Teacher Responses Students' Topics + Students' Responses
ARS index (average responses per student).	$ARS = \frac{\text{Students' Topics + Students' Responses}}{\text{Participant Students}}$

2. Network graphs for the 132 asynchronous discussion forums were generated and the statistical values of centrality and strongly connected components were obtained.

The centrality scores were used to calculate the centralization values for each of the 132 forums applying Freeman's general formula for centralization (Adamic, n.d.). Centralization values ranged between 0 and 4. There were 19 forums with a centralization value of 0 and 26 forums the centralization values were greater than 1. It was observed that values over 0.60 formed star shaped graphs with a central node which in most of the cases was the teacher.

Strongly connected components (SCC), were found in 81 of the 132 forums and their values ranged from 0.18 to 1.00.

3. With the centralization and SCC values, the collaboration index was calculated for the 132 forums using the CI formula CI = (1-C)(SCC).

There were 51 forums with a CI = 0. This was a result of having 51 forums without strongly connected components, this is, SCC = 0. Applying the CI formula, the CI was equal to 0. This means that in 51 forums there was no dialogue, in some cases participants addressed other participants but they received no answer. The students were participating but not collaborating.

There were 8 forums with a CI = 1. This is a result of having a centralization value equal to 0 and a SCC value equal to 1 and it indicates a perfectly distributed collaboration. In this case it was a result of the number of participants in the forums. In 6 of the 8 forums there was only one student and the teacher, in the other 2 there were two students and the teacher.

There were 48 forums with a CI between 0.76 and 0.00.

In 25 forums, the collaboration index resulted in negative numbers between - 0.03 and -3.00. These 25 forums formed star shaped graphs that represented different levels of heavily centralized collaboration.

For each of the 17 teachers who moderated asynchronous discussion forums, the forum with the highest collaboration index was identified as shown in Table 3.

Table 3.
Highest CI per teacher

Teachers 17	Cour-ses 32	Forums 132	Students 1910	**Highest CI index**	Ss in highest CI index	Partici-pation mandatory	Lowest CI
A	1	3	14	**0.1000**	6	yes	0.00
B	5	25	679	**0.3214**	7	yes	0.00
C	1	7	52	**0.1786**	7	no	-0.03
D	1	1	49	**0.0000**	49	no	0.00
E	1	12	109	**0.1296**	9	yes	0.00
F	2	1	9	**0.3306**	9	no	0.33
G	2	4	93	**0.1596**	24	yes	0.00
H	1	1	43	**0.2363**	43	yes	0.00
I	1	7	12	**1.0000**	1	yes	-1.67
J	1	4	44	**0.1990**	15	no	0.00
K	1	2	17	**0.1706**	8	no	-0.30
L	5	23	476	**0.7589**	36	yes	0.02
M	2	3	51	**0.1810**	15	yes	0.11
N	2	25	159	**1.0000**	1	yes	-2.00
O	2	7	27	**1.0000**	1	no	-0.30
P	2	3	48	**0.3458**	14	yes	-0.04
Q	2	4	28	**0.3095**	6	yes	0.00

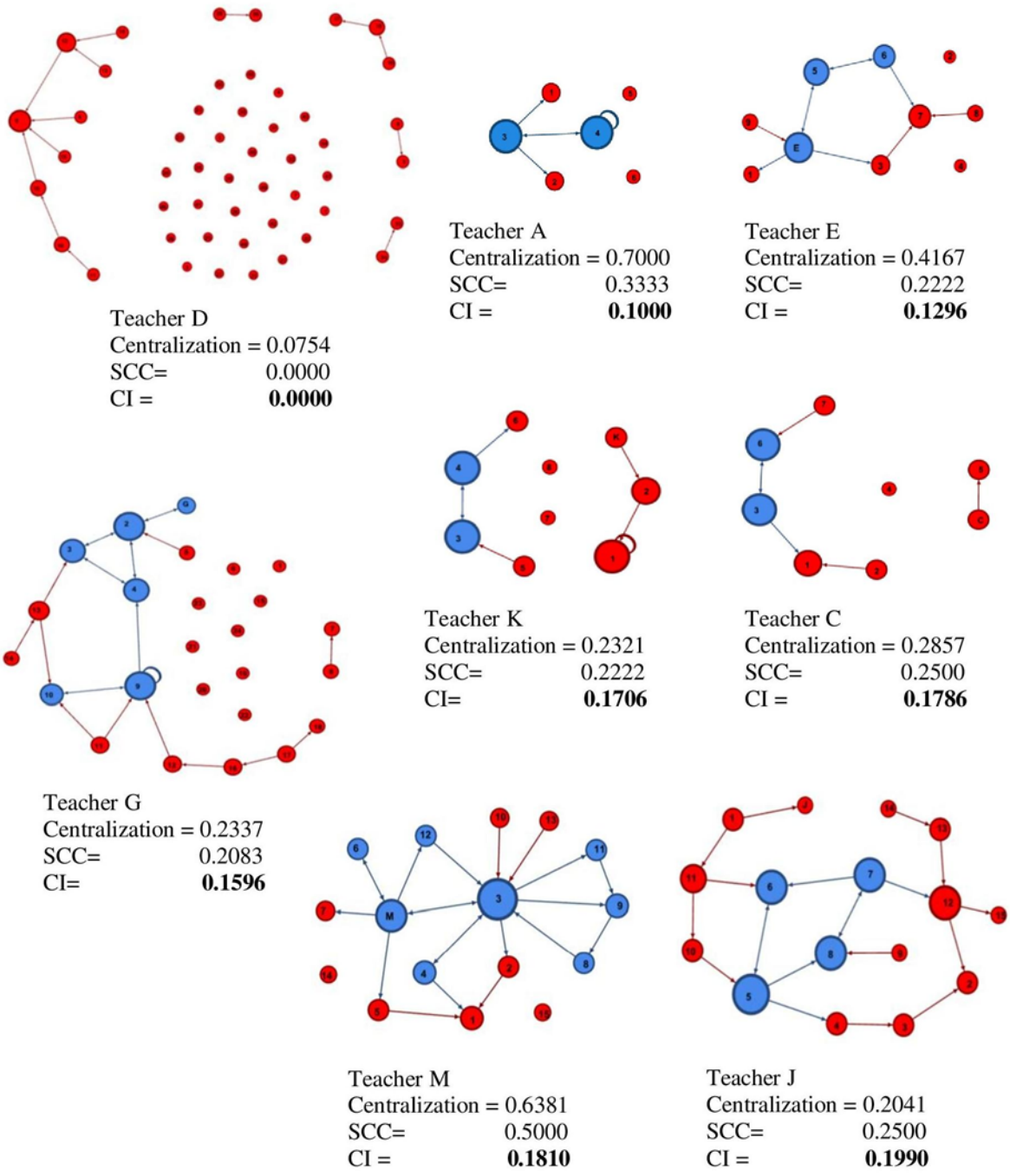
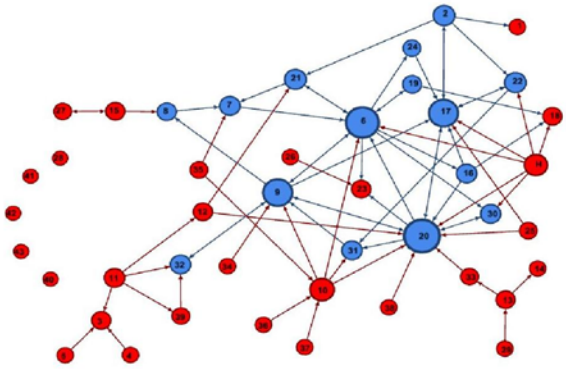
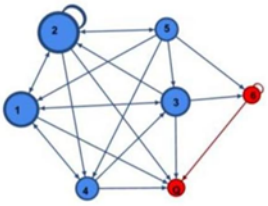


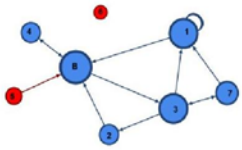
Figure 3. Networks and highest CI per teacher in ascending order, teachers D, A, E, G, K, C, M, J.



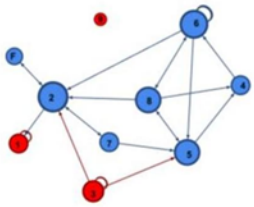
Teacher H
Centralization = 0.3068
SCC= 0.3409
CI = **0.2363**



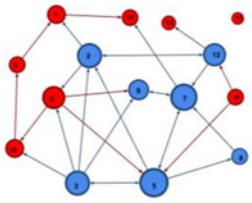
Teacher Q
Centralization = 0.5667
SCC= 0.7143
CI = **0.3095**



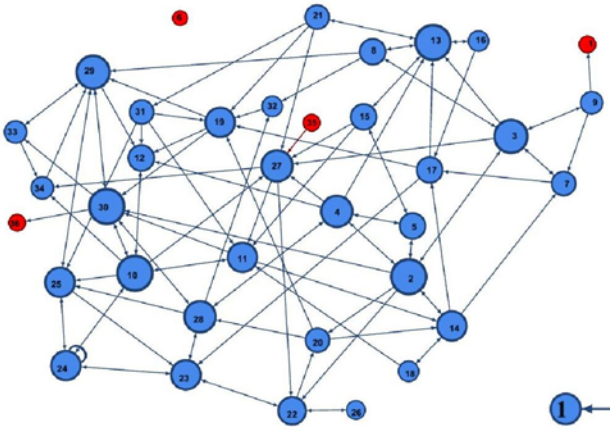
Teacher B
Centralization = 0.5714
SCC= 0.7500
CI = **0.3214**



Teacher F
Centralization = 0.5278
SCC= 0.7000
CI = **0.3306**

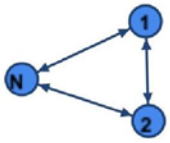


Teacher P
Centralization = 0.3516
SCC= 0.5333
CI = **0.3458**



Teacher L
Centralization = 0.1462
SCC= 0.8889
CI = **0.7589**

Teacher I
Centralization = 0.0000
SCC= 1.0000
CI = **1.0000**



Teacher N
Centralization = 0.0000
SCC= 1.0000
CI = **1.0000**

Teacher O
Centralization = 0.0000
SCC= 1.0000
CI= **1.0000**

Figure 4. Networks and highest CI per teacher in ascending order, teachers H, Q, B, F, P, L, N, I, O.

5. Regarding the possible association for the 17 forums with the highest CI scores with Identification elements of the courses and descriptive elements of the forums:

No association was found between the collaboration index and any of the identification elements of the courses or the descriptive elements of the forums: delivery type of the course, level of instruction, if the participation was mandatory or not, number of topics and responses of students or teachers, number of participants in the forums, number of courses each teacher instructs, or the average participation per student in the forums.

Differences in collaboration levels could be a result of teacher related factors like variations in technological skills, course design, forum moderation styles, or teaching background. Su, Bonk, Magjuka, Liu, & Lee (2005) mention another possible cause of low interaction levels, the teachers' old habits developed over years of teaching in face-to-face contexts transferred to the online settings. The differences could also be related to students, their previous knowledge, age, maturity, motivation to learn, difficulty of the assignment, or even emotional factors.

The heterogeneity of the context does not allow comparisons that could possibly result in associations. It's comparing apples and pears. To find a reliable indicator of collaboration, a content analysis would be needed. However, it would consume considerable amounts of resources and time. A content analysis is a guiding system, not a monitoring tool (Reffay & Chanier, 2003).

SNA provides the tools to develop monitoring systems for collaboration in asynchronous discussion forums. The proposed collaboration index can be calculated in a fast and easy way. Reffay and Chanier (2003) mention that "we need models which are easily computable in order to deal with the heterogeneous and large scale amount of data related to interactions". The collaboration index makes a useful monitoring tool for small and large scale discussion forums.

Conclusion

Results of this analysis provide evidence that methods of social network analysis can be used to identify levels of collaboration in asynchronous discussion forums in a practical and relatively simple way. The proposed collaboration index precisely and effectively identifies differences in the levels of collaboration among the members of a CSCL network. Approaches used in this study can serve to identify teachers' needs for training as discussion forums moderators to make the best use of this technological resource in online or hybrid courses.

A limitation of this analysis is that it does not report on vicarious interaction which refers to a student-self interaction and its impact on collaboration. An example of vicarious interaction is when a student responds silently to a comment or question of the teacher or a classmate although he does not actively participate in the discussion (Su et al., 2005).

It is necessary to conduct more empirical research to identify factors influencing the interaction and connectivity in discussion forums and especially to explore the quality of the knowledge students construct in relation with the collaboration index.

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