An Analysis of Density and Degree-Centrality According to the Social Networking Structure Formed in an Online Learning Environment

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ABSTRACT

In this study, we assessed the communication structure in an educational online learning environment using social network analysis (SNA). The communication structure was examined with respect to time, and instructors' participation. The course was implemented using ELGG, a network learning environment, blended with face-to-face sessions over a 14-week period. Data were collected from 114 undergraduate students who were enrolled in Instructional Technology and Material Design course. The program functions on the basis of a matrix; in this case a square matrix with rows and columns being the students' ID numbers. Density and centrality measures were visualized and interpreted. In terms of the density of the groups, it was found that the lowest density occurred during the first week. The highest density, on the other hand, occurred during the week when the instructor participated, in all the groups except for the third and sixth groups. The students placed in the center and those on the edges of the network differed on the basis of time as well as the instructor's participation. Other online learning environments could be assessed in a similar fashion using SNA in order to understand levels of participation and changes in interaction over time.

Keywords

Social network, Density, Centrality, Social network analysis

Introduction

Online learning environments may be inadequate in terms of establishing collaboration, giving feedback and receiving social support - which are relatively easier to achieve in traditional educational environments; this may influence the interpersonal relations in the learning environment. It is an indispensable component for the new generation of students, labeled as digital natives, to share by using innovative technological instruments such as social networks, blogs - to obtain and to create knowledge - and maintain high levels of communication. Social networking relies on the relationships students form among each other. Social networks become conduits for information, knowledge sharing and much more – it also affects members' behaviors (Grunspan, Wiggins & Goodreau, 2014).

Using social networks in educational and instructional contexts can be considered as a potentially powerful idea simply because students spend a lot of time on these online networking activities (Mazman & Usluel, 2010). For example, social networks facilitate the process of communication between students and teachers, ensure their participation, offer peer support, and support cooperative learning. Today, teachers are able to re-shape the learning-teaching process through social networks formed in online learning environments by means of Web 2.0 technologies. Both synchronous and asynchronous communication is possible in these online environments where learners and educators communicate using such tools as forums and blogs. It would be both difficult and time-consuming for educators to analyze those messages manually (Rabbany, Takaffoli, & Zaïane, 2011). The statistical analyses of those messages have informed us only the frequency of messages students between each other until recently. Yet, there was the likelihood of making mistakes in those analyses as well and these analyses occasionally failed to inform us about learner-teacher and learner-learner communication. The communication patterns of students who are in the center position as well as their social behaviors can be analyzed by means of SNA. The rate of knowledge sharing through online communication can be identified in this way, while the significance of the patterns that emerge can be analyzed. Students in key roles can affect the flow of communication, and influence the amount of information and communication, thereby affecting interpersonal cooperation in a teaching and learning environment. Therefore, giving important responsibilities to key actors in a group can make learning more effective, but only if the instructor understands the characteristics of the network formed by students.

SNA is employed in order to study social networks, i.e., to reveal the multi-relations between organizations, employees, clients and students. Network data are used to find out how knowledge is transferred between individuals or to test the efficiency of organizations in terms of knowledge flows. Cela, Sicilia and Sánchez (2015) state that, when applied to learning activities, SNA usually aims to identify factors that influence the success or efficiency of the educational process. SNA-related research studies are seen to have found their way into educational environments since they help to identify the patterns between individuals who are part of the same social network such as students in the same class. This is due largely to data that enable research to become knowledgeable about the importance of social communication in online learning environments. Amongst others, network characteristics affect learners' achievement (Penuel et al., 2006; Cho et al., 2007; De Laat et al., 2007; Grunspan, Wiggins & Goodreau, 2014). The relations among members interacting with each other in a social circle can be mapped (Wasserman & Faust, 1994). Those patterns that emerge can help us to model the flow of information between participants. De Laat et al. (2007) demonstrates what can be done with SNA in learning environments as follows:

- Since group behaviors are not static, researchers can find answers through SNA to the questions about relationships such as students-students and students-teachers and how these affect learning in learning environments and how they develop their competencies.
- Patterns of interaction on how the flow occurs between members can be revealed. While some of the participants move towards the center of the network, some others get away from the center. Thus, it can clearly be seen who manages the discussion and who is dominant.
- Relations amongst participants in a network, both direct and indirect, can be visualized, measured and analyzed.
- When used in combination with other methods such as content analysis and interviews, SNA can offer detailed information on learning and teaching processes.
- It enables us to monitor the changing relations between group members, the contributions made, and the experiences.

Social networks consist of actors and their relations. These are indicated as nodes while ties bind those nodes that have a relationship. In the case of an online learning environment, the communication flow between students (nodes or actors) is indicated by ties (links or edge) between those nodes that communicate. The network is the combination of a series of ties between students or a set of relations between them (Haythornthwaite, 2005). The students' positions in the network can be determined by means of the measurements performed with SNA and it is possible to demonstrate the way their positions affect their learning environment. The measurements that are most frequently used in research studies are degree, betweenness and closeness centrality, which are analyzed within the scope of density and centrality.

SNA is an important method of analysis for determining students' patterns of communication and interaction, for raising efficiency and for ensuring continuity. In short, it is possible to state that SNA offers alternatives distinct from traditional research methods and more realistic in evaluating communication patterns among students, especially in online learning environments given the ease with which network data can be obtained. To the best of our knowledge, there is a limited number of studies that analyze the structure of the social network in educational settings. In previous research, SNA was used to examine how learner networks evolve over time (De Laat et al., 2007), to examine using communication channels to achieve their educational goals (Haythornthwaite, 1999), to create patterns of relationships connecting teachers in networks (Ryymin et al., 2008), to determine the position of individual students' influence in learning outcomes (Cho et al., 2007). Consequently, it may be said that social networks are the important components in regulating the online learning environments. Based on this fact, this study aims at examining how students' social network structures change over a set period of time in an online learning environment. For our purposes, answers are sought to the following questions:

- What are the density measures of student groups?
    - How does the group of students' density change on the basis of time?
    - How does the group of students' density change on the basis of the instructor's participation?
- What is the students' degree centrality?
    - How does students' degree centrality change on the basis of time?
    - How does students' degree centrality change on the basis of the instructor's participation?

Methodology

Participants

The Instructional Technology and Material Design course was offered over a 14 - week period using ELGG, which is an online learning environment that augments contact sessions. Data were collected from 114 undergraduate students who were enrolled in this course offered by the educational faculty of a foundation university located in Ankara. 89% (n = 102) of the participants were female whereas 11% (n = 12) were male (Table 1).

Table 1. The number of students according to gender and groups

Group			*N*	%
Group 1 – Pre-school Teaching	Gender	Female	24	
		Male	-	21.05
		Total	23	
Group 2- - Elementary School Teaching	Gender	Female	20	
		Male	2	19.30
		Total	22	
Group 3 – Elementary Mathematics Teaching	Gender	Female	7	
		Male	4	9.65
		Total	11	
Group 4 –Mixed (Pre-school and Elementary Mathematics Teaching)	Gender	Female	22	
		Male	-	19.30
		Total	22	
Group 5 – Turkish Teaching	Gender	Female	14	
		Male	3	14.92
		Total	17	
Group 6 – English Teaching	Gender	Female	15	
		Male	3	15.78
		Total	18	

Data analysis

The methods for mathematical measurement and calculation used in identifying and analyzing the social network differ from the ones used in the analysis of any quantitative research in social sciences. Some measurements, such as degree centrality, between centrality are employed in the SNA in describing the students' positions in a network, in identifying the inter-student relations, and in determining a network formed as a whole. The SNA is used so as to analyze the structures of any type, which are in relation to one another or to the institutions, individuals or groups within the social structure (Wasserman & Faust, 1994; Freeman, 2004).

UCINET 6.0, one of the most well-known and the most frequently used software application when performing SNA, was also used in this study. The program functions on the basis of matrix, and it has a text-based format. The NetDraw program was used, however, for the visualization of the network.

Determining the actors' roles through SNA is important in understanding the effects of the roles on the network structures. In the present study, the structure of social network was analyzed through the measurements of density and degree centrality.

Density: Density is defined as the proportion of ties existing in the social network to all probable ties (Borgatti, 2003). It displays the frequency of information flow between individuals. The density or the scarcity of the ties emerges as a property of the network. A dense network is a network in which the number of ties is close to the maximum. A network with small number of ties is called scarce. The density of a network is calculated by dividing the number of ties in the network into the probable number of ties available in case the network is a full network. Consequently, density shows the percentage of the ties used which are potentially usable (Gürsakal, 2009). It receives values between 0 and 1 in the binary number system. The 0 value demonstrates that there are no ties between students while 1 or above value shows the number of ties through which a student communicates with other students. As a unit of density, 100% demonstrates that each individual has talked to all individuals at least once (Lowes, Lin & Wang, 2007).

Centrality: Centrality measures the importance of students within a network, and shows which students are in the center (Borgatti & Cross, 2003). It provides information on the position of students in the network. The individuals in the center within the network are called stars. They are the most popular people in the network. All network centralization measures may range from 0 to 100%. 100% as the unit of centrality means that all participants talk to one single individual (Lowes, Lin & Wang, 2007). Degree centrality, betweenness centrality and closeness centrality are the commonly used centrality measures.

Degree centrality shows the actors' degree of direct ties with the others in the network. An actor may be tied to another actor in linear relations in the ties. Generally, the higher is an actor's number of ties, the more important and powerful he is. The actor with the highest degree centrality can be said to be the most active actor in the network. The measurement of degree centrality can help to identify the active participation of the key characters in an online discussion (Kale, 2007).

Data collection

Data obtained from the selected online course provided the matrix necessary for analysis using UCINET 6.0. However, the online learning environment used in the research did not enable us to obtain the data matrix directly. Therefore, the data matrix was derived from the environment through SQL code that provided the researchers with the required matrix data. The required matrices with this SQL code were then created automatically in Excel prior to importing into UCINET. This way, the necessary matrices for analysis were obtained automatically.

The matrices to be formed with the data coming from the network-learning environment are needed for the SNA. Those matrices can be used as the source of data and analyses can be performed on the UCINET 6.0 program. Adjacency matrices are usually used for the data in SNA. This stems from the fact that adjacency matrices show who is close to whom or which students are adjacent to another students' social field. The students in the network are placed in the columns and lines of the matrices, and the number of ties between students is placed in the lines and columns in the binary or the decimal number system. The number of ties is placed in the matrices in binary or decimal number system according to the properties of the variable analyzed. Whether there are relations between students is to be revealed, the matrices encoded as 1; and otherwise it is encoded as 0. The density of student groups was calculated through binary adjacency matrix and the centrality was calculated through decimal adjacency matrix based on students' number of ties. An example of decimal and binary adjacency matrix of research data are given below.

Table 2. Example of decimal adjacency matrix of research data

	A97	A103	A96	A98	A94	A95	A93	A104
A97	0	7	9	1	2	3	3	0
A103	3	0	3	0	0	1	0	0
A96	9	3	0	1	2	5	3	0
A98	0	1	0	0	0	0	0	0
A94	1	1	1	0	0	0	1	0
A95	2	3	3	0	1	0	0	0
A93	3	1	1	1	0	0	0	0
A104	1	1	0	0	0	0	1	0

Table 3. Example of binary adjacency matrix of research data

	A97	A103	A96	A98	A94	A95	A93	A104
A97	0	1	1	1	1	1	1	0
A103	1	0	1	0	0	1	0	0
A96	1	1	0	1	1	1	1	0
A98	0	1	0	0	0	0	0	0
A94	1	1	1	0	0	0	1	0
A95	1	1	1	0	1	0	0	0
A93	1	1	1	1	0	0	0	0
A104	1	1	0	0	0	0	1	0

The discussion data for the six sub-groups formed in a network-learning environment in a 6-week period constitute the research data. A total of 36 data matrices were formed by using the data. The students' names were encoded by systematically. Students' names were encoded with alphabetical letters (A, B, C, D, E, and F) and the

instructor was coded with (G). Then, the analyses were performed by using those codes in the research in order to ensure anonymity.

Findings

Based on the research problems, the findings are listed as in the following:

How is the density of student groups?

How does the group of students' density change on the basis of time?

The density of the student groups was calculated according to weeks (Table 2). García Hernández and Reyes López (2009) reported that the middle level value of density measurement is between 40% and 70% in SNA. These values are interpreted taking into account the density of the group.

Table 2. The density of the student groups by weeks

Group	Week1	Week2	Week3	Week4	Week5	Week6
1	0.34	0.53	0.42	0.69	0.60	0.71
2	0.20	0.36	0.63	0.62	0.49	0.71
3	0.62	0.62	0.62	0.60	0.76	0.69
4	0.17	0.29	0.48	0.52	0.51	0.45
5	0.16	0.50	0.45	0.76	0.56	0.56
6	0.25	0.30	0.43	0.56	0.63	0.61

Group 1: It is clear that the density for the first group was the lowest (0.34) in the first week whereas it was the highest (0.71) in the sixth week. Accordingly, it may be stated that a low level of communication occurred in the first week and a high level of communication occurred in the sixth week in the discussion environment in which there were eight students.

Group 2: The density for the second group was the lowest (0.20) in the first week whereas it was the highest (0.71) in the sixth week. It is remarkable that there is a continuous increase until week five, followed by a decrease in week five, and then it reaches the highest level in week six. The density of communication in this group has increased continuously until the fifth week, but fell in the fifth week. Face-to-face course couldn't be conducted this week due to national holidays.

Group 3: The density for the third group was the lowest (0.60) in the fourth week whereas it was the highest (0.76) in the sixth week. It is evident that the density of communication is very close in weeks apart from week six. There were twenty-five students in first week while there were twenty students in fourth week. Accordingly, it is possible to say that in all weeks of intensive message exchange occurred in this group.

Group 4: The density for the fourth group was the lowest in the first week whereas it was the highest in the fourth week. It was observed that the density of communication increased until week four, but it decreased after week four. It was 0.17 for the first week while it was 0.52 for the fourth week. Accordingly, it is possible to say that in general the message of the change at least the whole week in this group that consist of two different groups of students.

Group 5: It is clear that the density for the fifth group was the lowest (0.16) in the first week whereas it was the highest (0.76) in the fourth week. There were nineteen students in first week while there were eleven students in fourth week. Instructors have attended the fourth week in this group. It is noteworthy that after this week, the density of communication was felt away.

Group 6: The density for the sixth group was the lowest (0.25) in the first week whereas it was the highest (0.63) in the fifth week. There were nineteen students in first week while there were fourteen students in fourth week. Instructors have attended the fourth week in this group as same as group 5. Contrary to the group 5, density of communication increased after this week.

On examining the density of all groups in general, it was found that the lowest density was in the first week in all the groups except for group three while the lowest density for group three was in the fourth week (Figure 1).

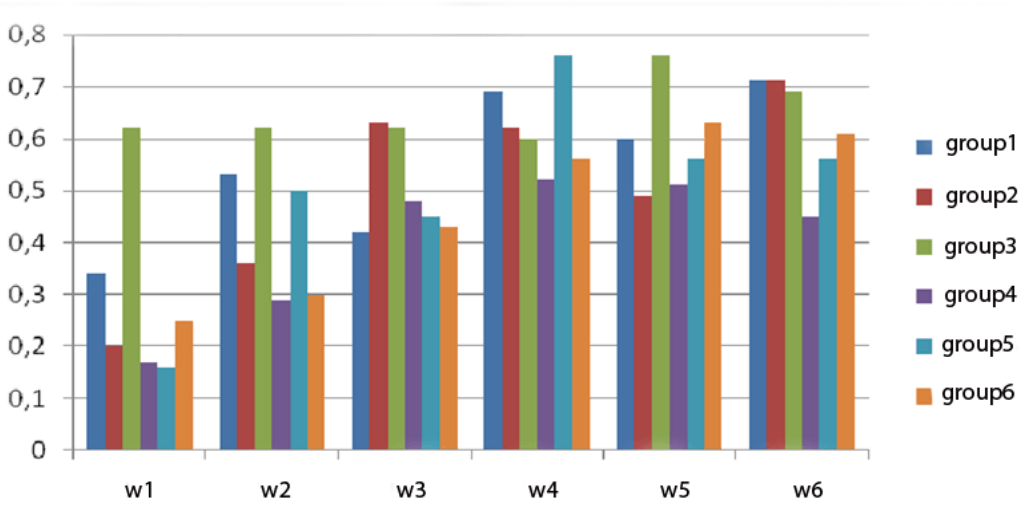

Figure 1. The density of the student groups on the basis of time

How does the group of students' density change on the basis of the instructor's participation?

While the instructor participated in the discussion held in week six in the first, second and third groups; the instructor did not participate in the discussion held in week four in the fourth, fifth and sixth groups. The density was at the highest level in all groups apart from group six in the weeks when the instructor participated. The highest level for group six was in week five- a week after the participation of the instructor. Besides, it was also remarkable that the density was higher in week six than that in week four.

It was also remarkable that the highest density in groups apart from group six was in the weeks when the instructor participated. In group six, however, the instructor participated in the fourth week, and the highest level of density was in the following week- that is, in the fifth week. The density of group was higher after week four- the week of instructor's participation-than in the previous weeks.

What is the students' degree centrality?

The number of students' ties with the others was taken into consideration in calculating the degree centrality. It was stated that the student with the most ties had the highest degree centrality whereas the student with the fewest ties with others had the lowest degree centrality. Accordingly, the student with the most ties with others is in the centre while the one with the fewest ties is outside the network.

How does students' degree centrality change on the basis of time?

The results of analysis performed through SNA in relation to the students' degree centrality on the basis of time are shown in Table 3. It shows only the number of student in the center of the network. Some weeks while one student place in the center of the network, some weeks there were more than one student in the center of the network. Accordingly, it is clear that the network maps are complex and dense with some groups whereas they are scarce with some other groups. One of the basic reasons for this is the number of students participating in the environment in that week. As is seen from the examples, while there were 8 students in group six; in week six, there were 25 students in group four in week one. The network maps showing the degree centrality for all groups by weeks are visible in Figure 2, Figure 3, Figure 4, Figure 5, Figure 6, and Figure 7.

According to the degree centrality measurement results, the students with high degree centrality and the students with low degree centrality in the groups are shown in the network maps (sociograms). The students marked in red are the students with the highest degree centrality in the network while the ones marked in blue are the students with the lowest degree centrality.

Table 3. The students with high degree centrality on the basis of time

Dimension	Theme	Weeks					
		1	2	3	4	5	6
Group 1	Number of students	1	1	1	1	3	4
	Percentage of centralization of the network	67%	45%	58%	38%	36%	19%
Group 2	Number of students	2	1	2	1	1	1
	Percentage of centralization of the network	67%	55%	35%	35%	33%	43%
Group 3	Number of students	1	1	2	1	2	5
	Percentage of centralization of the network	47%	35%	34%	49%	31%	26%
Group 4	Number of students	1	1	1	1	1	1
	Percentage of centralization of the network	59%	59%	40%	48%	30%	39%
Group 5	Number of students	1	1	1	1	1	3
	Percentage of centralization of the network	87%	43%	55%	42%	51 %	18%
Group 6	Number of students	1	1	1	1	2	2
	Percentage of centralization of the network	65%	81%	49%	42%	35%	50%

Group 1: According to the Figure 2, a student (A96) has the highest degree centrality for all weeks. In week five, two students in addition to that student were also placed in the center, and two more students were added to them in week six. Although the number of participation in the discussion environment was small in week six, all except two students actively sent messages to one another, which is remarkable. On seeing the network as a whole, the network centrality values were found as 67.95%for the first week, 45.45% for the second week, 58.97% for the third week, 38.89% for the fourth week, 36.11% for the fifth week, and 19.05% for the sixth week. It may be said that centrality was not available in the fourth, fifth and sixth weeks.

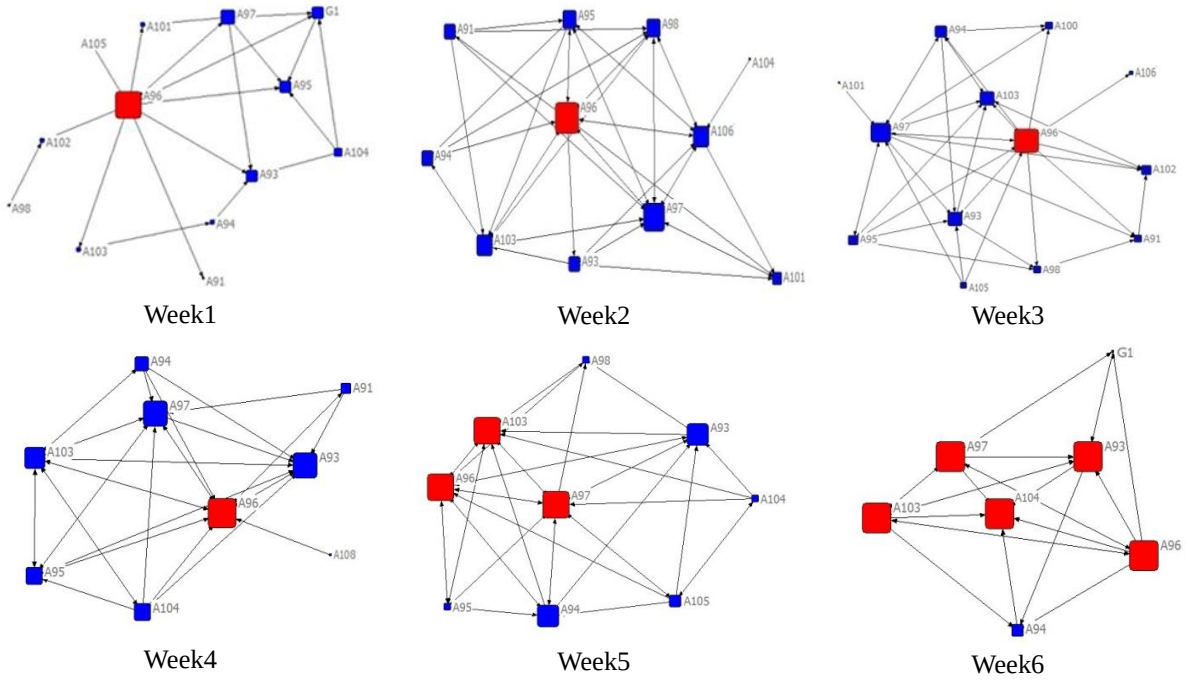

Figure 2. The network maps for the Group1

Group 2: While there were two students with the highest degree centrality in weeks one and three, there was only one student with the highest degree centrality in the other weeks. It was found that some students sent messages only to their groups in the first week. On seeing the network as a whole, the network centrality values were found as 67.14% for the first week, 54.76% for the second week, 35.42% for the third week, 35.71% for the fourth week, 33.33% for the fifth week, and 42.86% for the sixth week. It may be said that centrality was not available in the third, fourth and fifth weeks.

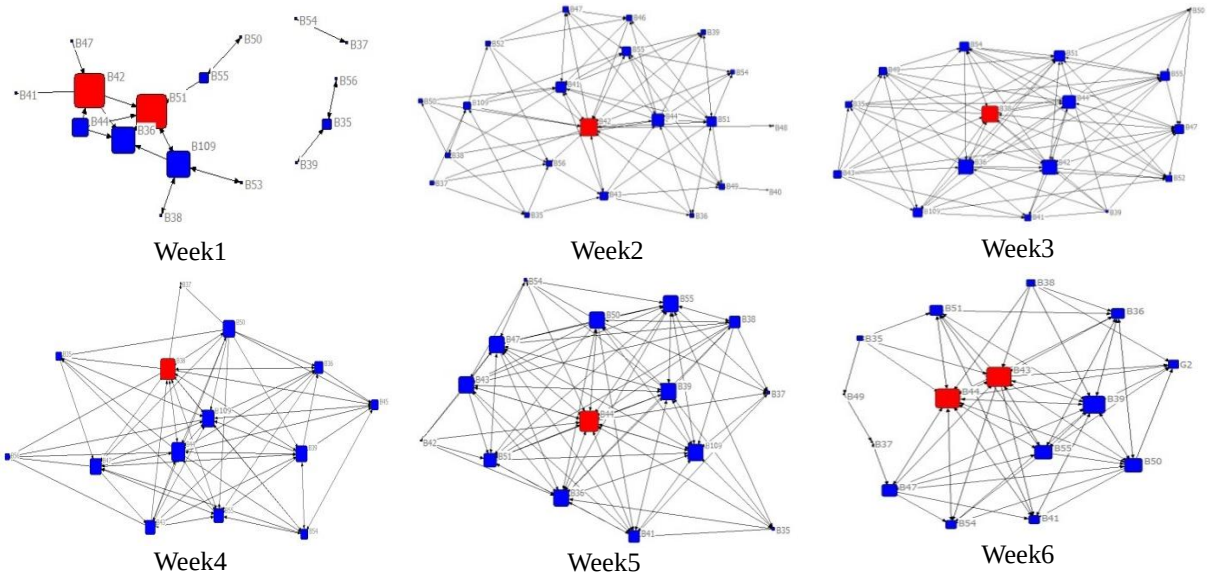

Figure 3. The network maps for the Group 2

Group 3: On examining the degree centrality by weeks, it was found that different students achieved high degree centrality each week. While only one student attained the highest score in weeks one, two and four; more than one student did so in the other weeks. In week six, two students who had not attained high degree centrality before were added to the students who had attained the highest degree centrality scores in at least one of the first five weeks, and thus five students attained the highest scores in week six. On seeing the network as a whole, the network centrality values were 46.67% for the first week, 34.55% for the second week, 34.44% for the third week, 48.89% for the fourth week, 30.56% for the fifth week, and 25.56% for the sixth week. It may be said that centrality was not available in the second, third, fifth and sixth weeks.

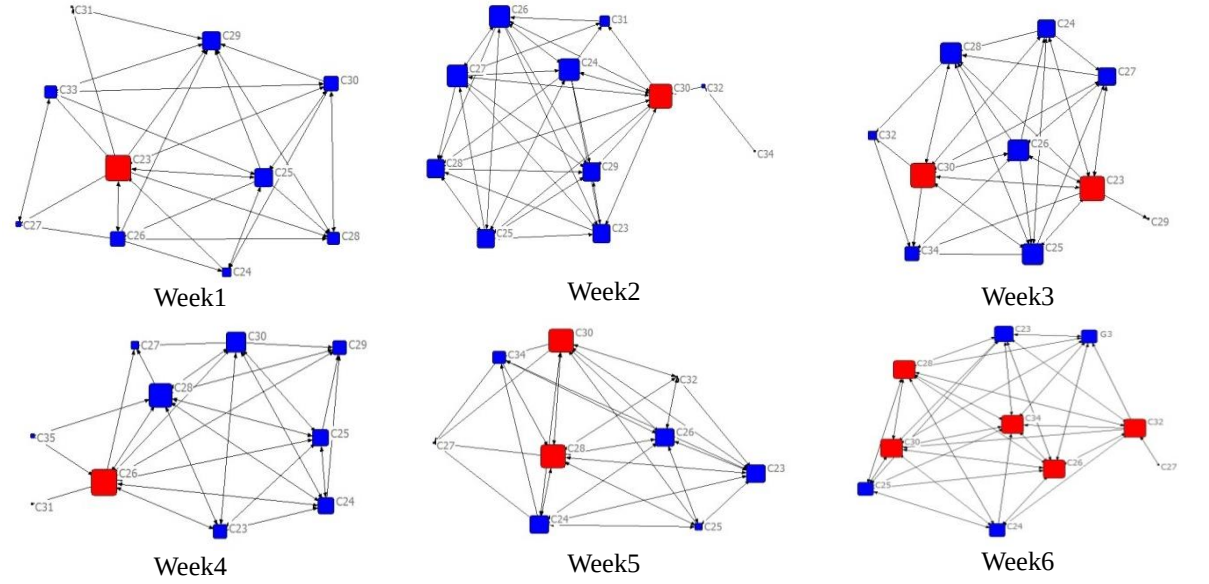

Figure 4. The network maps for Group 3

Group 4: On examining the degree centrality across the weeks, it was found that the same student (D2) always attained the highest degree centrality for six weeks. It was remarkable in the second week that a group was formed and messages were sent within the group only. On seeing the network as a whole, the network centrality values were found as 59.33% for the first week, 59.06% for the second week, 39.71% for the third week, 47.37% for the fourth week, 30.03% for the fifth week, and 38.95% for the sixth week. It may be said that centrality was not available in the third, fifth and sixth weeks.

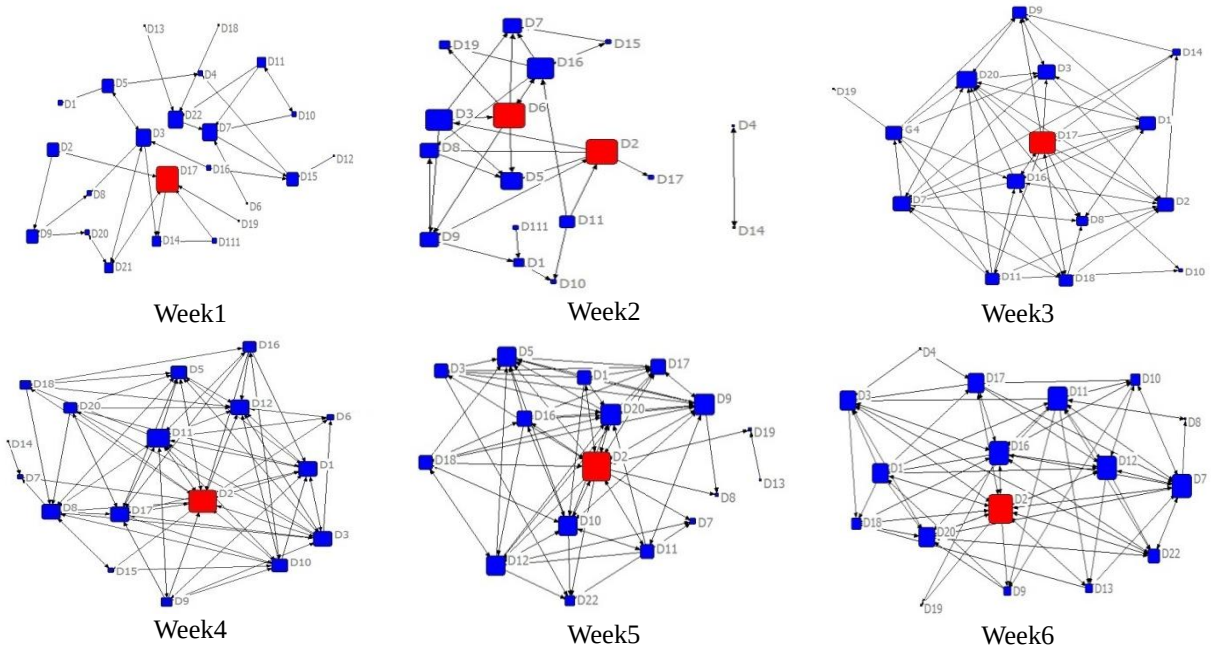

Figure 5. The network maps for the Group 4

Group 5: On examining the degree centrality by weeks, it was found that there was one student (E66) attaining the highest degree centrality four times. While only one student attained the highest degree centrality in the first five weeks, three students did so in the sixth week. It was remarkable that several students set up ties with only one student in the network structure formed in the first week. On seeing the network as a whole, the network centrality values were found as 87.25% for the first week, 42.5% for the second week, 55.13% for the third week, 41.82% for the fourth week, 51.28% for the fifth week, and 18.18% for the sixth week. It may be said that centrality was not available in the sixth week only.

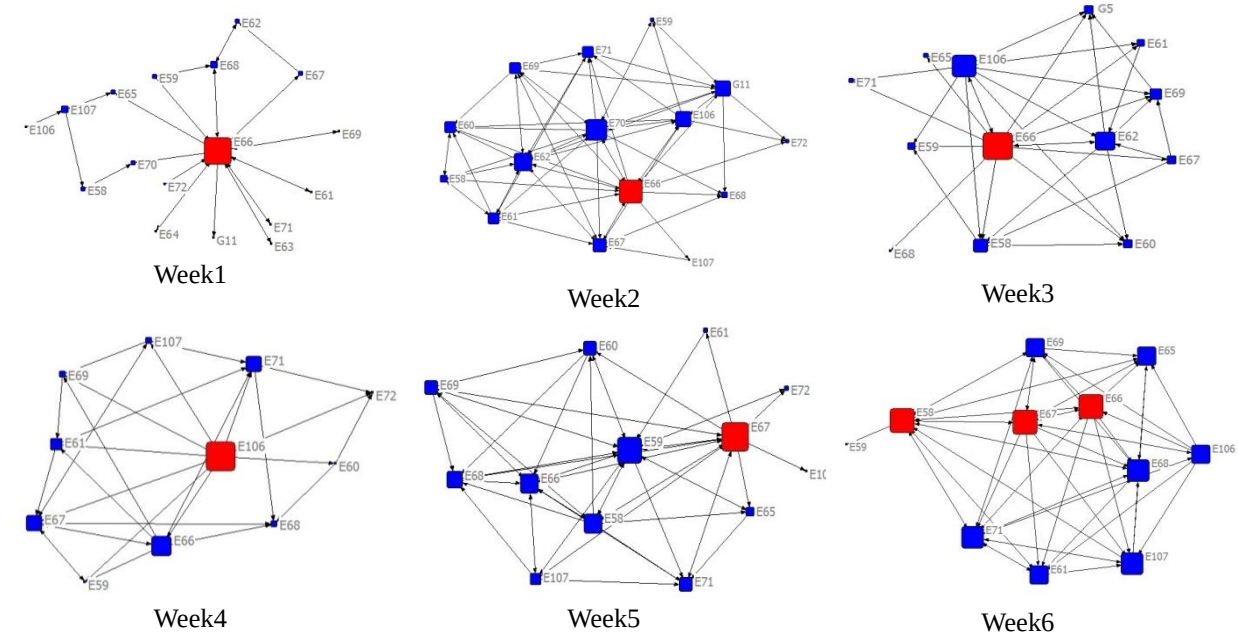

Figure 6. The network maps for the Group 5

Group 6: On examining the degree centrality by weeks, it was found that there was one student (F74) attaining the highest degree centrality four times. While only one student attained the highest degree centrality in the first four weeks, two students did so in the fifth and sixth weeks. It was remarkable that the number of students participating in the discussion decreased in the sixth week. On seeing the network as a whole, the network centrality values were found as 65.03%for the first week, 81.32% for the second week, 49.45% for the third

week, 42.31% for the fourth week, 34.62% for the fifth week, and 50% for the sixth week. It may be said that centrality was not available in the fifth week only.

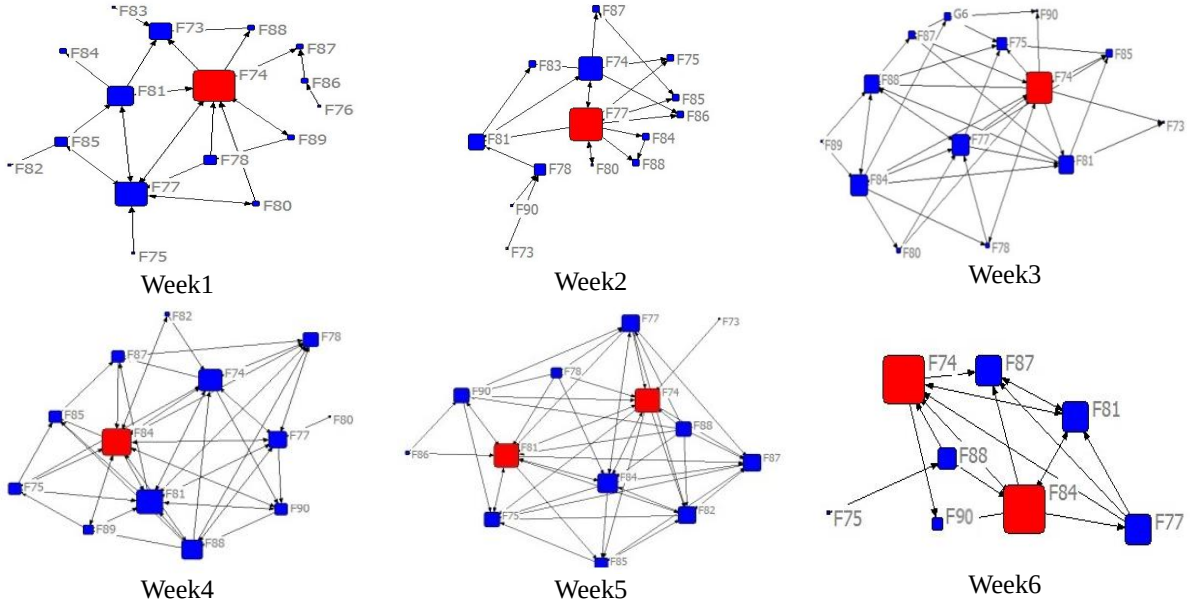

Figure 7. The network maps for the Group 6

In summary, the network centrality was the highest for all groups in the first week. It may be said that the distribution of students within the network was not very high in the weeks with low percentages of network centrality. It was remarkable that there were not groupings in two groups except for two weeks.

How does students' degree centrality change on the basis of the instructor's participation?

The instructor participated in the first, second and third groups in week six and in the fourth, fifth and sixth groups in week four. The students' degree centrality scores were examined for those weeks. There were five students attaining the highest degree centrality in the first group. Only one student attaining the highest degree centrality was available in the second group. That student participated in the environment in the other weeks, but could not attain the highest score. In the third group, there were three such students. This was the group with the most students in the center of the network. While one of those students did not participate in the environment apart from that week, the other student remained outside the network in another week. There was one student attaining the highest degree centrality in the fourth group. It was found that that student attained the highest degree centrality in the fifth and sixth weeks also. There was one student attaining degree centrality in the fifth and sixth groups. These students attained the highest degree centrality some weeks or had achieved a high degree centrality other weeks. In conclusion, according to the results of degree centrality, the number of students placed in the center of the network increased in the weeks when the instructor participated while the number of students remaining outside the network decreased.

Discussion

This study maps the relations among students enrolled for the Instructional Technology and Material Design course by using SNA. In line with our purpose, the relational data were collected via the forum formed in the online learning environment. The data were then transformed into sociometrical matrices in a statistical program performing the SNA. In accordance with the research problems, the density and centrality measures were used, and the data were visualized and interpreted.

Density measurement provides a prediction of the diffusion rate of knowledge between actors. Martino and Spoto (2006) point out that density is an indication of homogeneity of the group and actors' engagements to each other. Therefore, if individuals who have a high density leave the online learning environment, the lack of communication network and the flow of knowledge can also be said to slow down in the group. On examining the density of the groups in this study, it was found that the lowest density was in the first week. The highest

density was, however, in the other groups apart from the third and sixth groups in the week when the instructor participated. In this sense, Abedin, Daneshgar and D'Ambra (2014) also point out that the availability of an administrator in the environment supports students in terms of participation. It could be said that these students want to show themselves for having a good grade. When the number of students' messages were examined at the weeks of instructor's participation, the number of sending messages was greater than the number of receiving messages all of the groups. Yet, it may be said that the participation of the instructor did not affect the participation of the students in the discussion in both groups (group three and group six). An, Shin and Lim (2009) point out that students tend to be more comfortable in expressing their thoughts when instructors participate less to the online environment. On examining the time-dependent density, this case showed that either the density was high or it was low in all weeks in these two groups. Abedin, Daneshgar and D'Ambra (2014) state that facilitators can benefit from the students' non-task behaviors encouraging other students to behave in a similar fashion. For example, as a result of an association between reflections, thanks, salutations, and signatures, if the facilitator encourages students to share personal and work experiences with others, he or she may start the discussions with posting his or her own experiences. This, in turn, will encourage others to make similar posts.

The students' degree centrality scores were examined according to groups, and it was found that there were students in the center of and outside the network. The students placed in the center and remaining outside the network differed on the basis of time and of the instructor's participation. In the week when the instructor participated in the environment, the number of students remaining outside the network decreased. Phang, Kankanhalli and Sabherwall (2009) stated that individuals considered the existence of a moderator in information seeking behaviors more important than in the behaviors of contributing to knowledge. Gómez, Roses and Farias (2012), on the other hand, state that teachers were important in the academic use of social networks and in ensuring students' participation on checking the general network centrality values for all groups by weeks, it was found that it was in the 30%-60% range. This shows that students were not very active in the network. It may be said that the number of ties each student has in the network is close to each other. In brief, the students actively participating in the forum in the online learning environment, the ones leading the group in ideas and the ones with little importance in the group were determined with this measurement.

Degree centrality can be a measurement to determine the opinions of leaders. Rogers (2003) stated they are at the center of interpersonal communication networks. A communication network consists of interconnected individuals who are linked by patterned flows of information. It is important to adopt new practices and ideas within the group in order that opinion leaders take place in the online learning environment for ensuring the continuity of efficient resource sharing or discussion and raising the group dynamic. Opinion leaders communicate with others, develop social networks, manage and enable participation by communicating and helping. It is important for online learning communities to benefit from their strong and influential relationships with others in identifying, recognizing and motivating this people. It seems that the students at the center in groups varied according to the weeks. The number of messages sent by these students was determined to be greater than the number of messages received from others. Also, they generally started discussion with others. It can be said that they motivated others for participate to environment. In addition, it is observed in the network map that there wasn't any clustering all of the groups. This indicates that students are interconnected, be it directly or indirectly. This situation brings about the question of whether the effect of the course carried out both online and face-to-face environment.

According to the results obtained within the present study, the following recommendations are made:

- SNA is a powerful tool in measuring the interaction occurring in the learning process in the online learning environments (Rienties, Tempelaar, Bossche, Gijselaers & Segers, 2009). Even if only density and degree centrality were used in this study, different social network measurement would be used for to different purposes in online learning environments.

- Students' network centrality has correlated with learning achievement (Lin, Huang & Chuang, 2015). Students with high centrality outperform students with low centrality on learning achievement. Stepyan, Borau and Ullrich (2010) state that students showing higher reciprocal interaction also showed higher achievement scores. Another research suggests that the position in the network is positively related to learning performance in computer supported collaborative learning (Cho et al., 2007). Marcos et al. (2016) points that a positive correlation between students' performance and six of the metrics employed (degree, eigenvector centrality, betweenness centrality, hub, authority and PageRank). So, there will be a new study done about learning achievement with SNA.

- Besides increasing the density in online learning environments, the quality of the shared knowledge is also important. Therefore, the elements raising the quality rather than the quantity of the messages should be included. As the quality of the messages increases, it is recommended that experimental studies concerning how students' engagements changes should also be performed.

- This study analyzed all of the response messages. The system logs were used, so each response message, which includes all written message by students and teachers, can be task related or non-task related. For example, it contains encouraging words or chitchat words. A new study will be done only by excluding these types of non-related task messages used in combination with other methods such as content analysis or interviews in the future.

- Gladwell (2008) stated that "we are too much in awe of those who succeed and far too dismissive of those who fail." A need for studies investigating the content shared between both students in center and outliers, and the way in which they are shared ought to be beneficial to instructors and course designers.

References

Abedin, B., Daneshgar, F., & D'Ambra, J. (2014). Pattern of non-task interactions in asynchronous computer-supported collaborative learning courses. *Interactive Learning Environments, 22*(1), 18-34.

An, H., Shin, S., & Lim, K. (2009). The Effects of different instructor facilitation approaches on students' interactions during asynchronous online discussions. *Computers & Education, 53*(3), 749–760.

Borgatti, S. P., & Cross, R. (2003). A Relational view of information seeking and learning in social networks. *Management Science, 44* (4), 432–445.

Cela, K. L., Sicilia M. Á., & Sánchez, S. (2015). Social network analysis in e-learning environments: A Preliminary systematic review. *Educational Psychology Review, 27*(1), 219–246.

Cho, H., Gay, G., Davidson, B., & Ingraffea, A. (2007). Social networks, communication styles, and learning performance in a CSCL community. *Computers & Education, 49*(2), 309–329.

De Laat, M., Lally, V., Lipponen, L., & Simons, R., J. (2007). Investigating patterns of interaction in networked learning and computer-supported collaborative learning: A Role for social network analysis. *International Journal of Computer-Supported Collaborative Learning, 2*(1), 87–103. doi:10.1007/s11412-007-9006-4

Freeman, L. C. (2004). *The Development of social network analysis: A Study in the sociology of science.* Vancouver, BC: Empirical Press.

Gladwell, M. (2008). *Outliers: The Story of success.* New York, NY: Little, Brown and Co.

Gómez, M., Roses, S., & Farias, P. (2012). The Academic use of social networks among university students. *Scientific Journal of Media Education*, 38, 131-138.

Grunspan, D. Z., Wiggins, B. L., & Goodreau S. M. (2014). Understanding classrooms through social network analysis: A Primer for social network analysis in education research. *CBE—Life Sciences Education, 13*(2), 167–178.

Gürsakal, N. (2009). *Sosyal Ağ Analizi* [Social Network Analysis]. Bursa, Turkey: Dora Yayınları.

Haythornthwaite, C. (1999). Collaborative work networks among distributed learners. In *Proceedings of the IEEE the 32nd Annual Hawaii International Conference* (pp. 16-26). doi:10.1109/HICSS.1999.772707

Haythornthwaite, C. (2005). Social network methods and measures for examining e-learning. *Social networks, 2005*, 1-22. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.135.6993&rep=rep1&type=pdf

García Hernández, A., & Reyes López, E. D. L. (2009). *Analysis of the relationship between the properties of the social networks of R&D groups and their scientific performance.* Retrieved from http://www2.druid.dk/conferences/viewpaper.php?id=1950&cf=28

Kale, U. (2007). *Online communication patterns in a teacher professional development program* (Doctoral dissertation). Retrieved from ProQuest Dissertations and Theses database. (UMI No. 3277966)

Lin, J. W., Huang, H. H., & Chuang, Y. S. (2015). The Impacts of network centrality and self-regulation on an e-learning environment with the support of social network awareness. *British Journal of Educational Technology, 46*(1), 32-44.

Lowes, S., Lin, P., & Wang, Y. (2007). Studying the effectiveness of the discussion forum in online professional development courses. *Journal of Interactive Online Learning, 6*(3), 181-210.

Marcos, L., García-Lopez, E., García-Cabot, A., Amelio, J., Medina-Merodio, J. A., Domínguez, A., Martínez-Herraiz, J. J., & Diez-Folled, T. (2016). Social network analysis of a gamified e-learning course: Small-world phenomenon and network metrics as predictors of academic performance. *Computers in Human Behavior, 60*, 312- 321.

Martino, F., & Spoto, A. (2006). Social network analysis: A Brief theoretical review and further perspectives in the study of information technology. *PsychNology Journal, 4*(1), 53-86.

Mazman, S. G., & Usluel, Y. K. (2010). Modeling educational usage of Facebook. *Computers & Education, 55*(2), 444-453.

Penuel, W. R., Sussex, W., Korbak, C., & Hoadley, C. (2006). Investigating the potential of using social network analysis in educational evaluation. *American Journal of Evaluation, 27*(4), 437-451.

Phang, C. W., Kankanhalli, A., & Sabherwal, R. (2009). Usability and sociability in online communities: a comparative study of knowledge seeking and contribution. *Journal of the Association for Information Systems, 10*(10), 721-774.

Rabbany, R., Takaffoli, M., & Zaïane, O. R. (2011). Analyzing participation of students in online courses using social network analysis techniques. In Pechenizkiy, M., Calders, T., Conati, C., Ventura, S., Romero, C., & Stamper, J. (Eds.) *Proceedings of the 4th International Conference on Educational Data Mining* (pp. 21–30). Eindhoven, The Netherlands: EDM.

Rienties, B., Tempelaar, D., Van den Bossche, P., Gijselaers, W., & Segers, M. (2009). The Role of academic motivation in computer-supported collaborative learning. *Computers in Human Behavior, 25*(6), 1195–1206.

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). New York, NY: The Free Press.

Ryymin, E., Palonen, T., & Hakkarainen, K. (2008). Networking relations of using ICT within a teacher community. *Computers & Education, 51*(3), 1264–1282.

Stepanyan, K., Borau, K. & Ullrich, C. (2010). A Social network analysis perspective on student interaction within the twitter microblogging environment. In *Proceedings of the IEEE 10th International Conference on Advanced Learning Technologies (ICALT)* (pp. 70–72). doi:10.1109/ICALT.2010.27

Wasserman, S., & Faust, K. (1994). *Social network analysis: Methods and applications.* Cambridge, UK: Cambridge University Press.