UDC 378.147:378.18
Original Scientific Paper

Social Network Analysis of Study Environment

Blaženka Divjak *blazenka.divjak@foi.hr*
University of Zagreb
Faculty of Organization and Informatics Varaždin

Petra Peharda *petra.peharda@foi.hr*
University of Zagreb
Faculty of Organization and Informatics Varaždin

Abstract

Student working environment influences student learning and achievement level. In this respect social aspects of students' formal and non-formal learning play special role in learning environment. The main research problem of this paper is to find out if students' academic performance influences their position in different students' social networks. Further, there is a need to identify other predictors of this position. In the process of problem solving we use the Social Network Analysis (SNA) that is based on the data we collected from the students at the Faculty of Organization and Informatics, University of Zagreb. There are two data samples: in the basic sample N=27 and in the extended sample N=52. We collected data on social-demographic position, academic performance, learning and motivation styles, student status (full-time/part-time), attitudes towards individual and teamwork as well as informal cooperation. Afterwards five different networks (exchange of learning materials, teamwork, informal communication, basic and aggregated social network) were constructed. These networks were analyzed with different metrics and the most important were betweenness, closeness and degree centrality. The main result is, firstly, that the position in a social network cannot be forecast only by academic success and, secondly, that part-time students tend to form separate groups that are poorly connected with full-time students. In general, position of a student in social networks in study environment can influence student learning as well as her/his future employability and therefore it is worthwhile to be investigated.
Keywords: social network analysis, academic performance, teamwork

1. Introduction

1.1. Problem analysis

Student working environment plays important role in student learning. Apart from its formal aspects including lectures, homework, individual learning and communication with teachers, there is an informal aspect to the learning and teaching process including interactions among students, informal learning and non-learning, which involves sharing learning materials, working in teams or simply talking in a relaxed manner. The first aspect is more extensively investigated and described than the second one. Our aim is therefore to put the informal aspect of learning into the focus of research. In other words we try to put learning process in social context and to investigate student perspective. Ramsden in [11] points out that "It may be helpful to think about the relation between students' perception and their approaches at several levels. These are the learning task itself, the quality of interactions with lecturers, the curriculum and assessment, and, at the most general level, the atmosphere or "ethos" of the course, programme of the study or institution." Let us add that in the last level we also put student-student interaction, cooperation in learning and also exchange of material, experiences and sometimes even "institutional myths".

Furthermore, there is a need to analyze the position of part-time students and compare them with full–time students with respect to elements of informal learning and communication. Since scarce data on this topic are available, our ultimate aim is to conduct a pilot research and use the results obtained in it to derive a more detailed problem description and formulation of hypotheses for future research. In this first phase we focused on a community of students and investigated two types of networks. The first of them describes goal-oriented communication represented by teamwork and sharing of teaching materials whereas the second type involves informal communication. Then we form two additional networks so called basic network and aggregated network as intersection and union of the three abovementioned networks. Finally, our aim is to find out potential ways to enhance students' academic achievement through social networking. In that sense we can also influence employability of students because social networking include personal quality development (for example emotional intelligence, adaptability, willingness to learn etc.), core skills enhancement (like presentation skills, information retrieval etc.) and process skills upgrading (for example team work ability to work cross-culturally, ethical sensitivity etc.) as it is explained in more details in [7].

1.2. Literature review

There are many studies dealing with different factors affecting student achievement. However, very few of those studies use Social Network Analysis (SNA) as a tool for analyzing data.

For example, [3] did research into consideration intellectual ability, learning style, personality, achievement motivation and academic success of psychology students in higher education. The purpose of their study was to integrate intellectual ability, learning style, personality and achievement motivation in order to investigate how these variables relate to academic success in higher education. Their main findings have been that intellectual ability and achievement motivation are positively associated with academic success. In addition, conscientiousness, as a personality trait, appears to be a consistent and positive predictor of academic success.

Further, [4] investigated social networks, communication styles and learning performance in a computer-supported collaborative learning community using social network analysis (SNA) and longitudinal survey data. Their main findings have been that learners' performance is an actual outcome of emergent collaborative learning social networks and that network centrality significantly influences students' final learning performance, even indicating that some students are structurally advantaged or disadvantaged due to their network positions.

On the other hand, [8] combined qualitative evaluation and social network analysis for research into classroom social interaction. In their paper, a mixed evaluation method is presented that combines traditional sources of data with computer logs, by integrating quantitative statistics, qualitative data analysis and social network analysis in an overall interpretative approach. SNA is used for efficient investigation into social and participatory aspects of learning.

In [13] authors discussed the relation between team structure and IS development team performance using a social network approach. Their main findings have been that group cohesion was positively related to overall performance while group conflict indexes were not significantly correlated with overall performance. Further, group characteristics fluctuated in different phases and group structure seemed to be a critical factor for good performance.

Further, in [10] authors described the structure of the social network of junior high school students from a low socioeconomic status and assesses the association between centrality measurements and academic performance. The main findings of their study were that in the centrality positions the female gender and "only study" were significant predictors of high academic performance.

There are quite a lot of researches on virtual communities and some of them investigate learning virtual community. In [5] authors determined characteristics of the virtual social

network for overall communication for information technology students. Among others, they find out that "some of the most successful students, with extrovert personalities, are the stars of the three analyzed networks."

In well-known paper [9] author constructed networks of collaboration between scientists in physics, biomedical research, and computer science. Author studied many statistical properties of networks, including numbers of papers, written by authors, numbers of authors per paper, variety of measures of connectedness within a network. Using a selection of results, author suggests a variety of possible ways to answer the question "Who is the best connected scientist?"

2. Social network analysis

Usually, social network analysis is defined as the mapping and measuring of relationships and flows between people, groups, organizations, computers, web sites and other information/knowledge processing entities. The nodes in the network are the people and groups while the links show relationships or flows between the nodes. SNA provides both a visual and a mathematical analysis of human relationships [16]. The resulting structure has a structure of a mathematical graph and these graph-based structures are often very complex [16]. The (undirected) graph is ordered pair $G = (V, E)$, where $V = V(G) \neq \emptyset$ is a set of nodes (vertices) and $E = E(G)$ a set of edges where $E \cap V = \emptyset$ and every edge $e \in E$ connects two nodes $u, v \in V$ that are the ends of edge e.

Geodesic distance between two nodes in a network is the number of edges in a shortest path connecting them.

The length $max_{u,v} d_g(u, v)$ of the 'longest shortest path' (i.e., the longest graph geodesic) between any two graph vertices (u, v) of a graph, where $d_g(u, v)$ is graph diameter

$$diam\ G = max\{d_g(u, v) : u, v \in V(G)\}. \quad (1)$$

SNA has arisen as a key technique in sociology, but it has also gained a significant place in information science and organizational studies. At the same time it has been used in some fairly exotic areas of research when such tools are concerned, such as the analysis of rumor spreading and has proven to be an effective tool for mass surveillance.

There are many measures that can be defined for SNA [19]. Some of them are used in this paper and defined below.

Degree is the count of the number of ties to other actors (vertices) in the network and it is given by

$$C_D(n_i) = d(n_i) = \sum_{\forall j \neq i} x_{ij}\ , \quad (2)$$

where

$C_D(n_i)$	Degree centrality of actor i
$d(n_i)$	Degree of node i
x_{ij}	$\begin{cases} 1, if\ i\ is\ indicent\ to\ j \\ 0, if\ i\ is\ not\ indicent\ to\ j \end{cases}$
n	Number of nodes in the network

Centrality is the measure that gives a rough indication of the social power of a node (vertex) based on the network's internal 'texture'. Betweenness, closeness and degree are all measures of centrality.

Centralization is the difference between the number of links for each node divided by the maximum possible sum of differences. A centralized network will have many of its links dispersed around one or a few nodes, while a decentralized network is one in which there is certain variation between the number of links each node possesses.

$$r = \frac{\sum_{i=1}^{g}[\max(D_i) - D_i]}{(g-1)(g-2)} \tag{3}$$

where

D_i Number of actors in the network that are directly linked to actor i
g Number of actors

Betweenness refers to the extent to which a node lies between other nodes in the network. This measure takes into account the connectivity of the node's neighbors, giving a higher value to nodes which bridge clusters. The measure reflects the number of actors - people that a person is connecting indirectly through their direct links. It is defined as

$$C_B(n_i) = \frac{\sum_{j<k, i\neq j, i\neq k} \frac{g_{jk}(n_i)}{g_{jk}}}{\frac{((n-2)(n-1))}{2}}, \tag{4}$$

where

$C_B(n_i)$ Standardized betweenness centrality of node i
$g_{jk}(n_i)$ Number of geodesic linking j and k that contains i in between
g_{jk} Total number of geodesic linking j and k

It means that the betweenness measure of a vertex is the frequency of the shortest paths of any two vertices of the graph in which this vertex occurs. These vertices have a main role as they are essential to connect the whole graph. In social networks, they can be seen as mediating persons that link together subgroups that would be otherwise unrelated [2].
Closeness is the degree to which an individual is positioned near all the other individuals in a network (directly or indirectly). It reflects the ability to access information through network members. Thus, closeness is the inverse of the sum of the shortest distances between each individual and every other person in the network.

$$C_c(n_i) = \frac{n-1}{(\sum_{j=1, i\neq j}^{n} d(n_i, n_j))}, \tag{5}$$

where

$C_c(n_i)$ Standardized closeness centrality of node i
$d(n_i, n_j)$ Geodesic between i and j

The connectivity is an important concept in graph theory. Two vertices u and v are connected in a graph $G = (V, E)$ if there is a path $u - v$ in G. A non-empty graph is connected if any two vertices are joint by a path in G.
Component of graph G is a maximally connected subgraph of G.
Bridge is an edge and deleting it would cause its endpoints to lie in different components of a graph.
Density of social network is the proportion of edges in a network relative to the total number of possible edges.
Clique of a non-weighted graph is a complete subgraph i.e. a subgraph in which all vertices are pairwise linked by an edge.
Clustering coefficient is the measure of the likelihood that two associates of a node are associates themselves. A higher clustering coefficient indicates a greater 'cliquishness'.

3. Research on students' social networks

There are many situations in which students interact. In our research we focus on social network of teamwork in formal studying, learning materials exchange as well as informal communication among students. Further, we composed two additional social networks based on aforementioned social networks. In order to analyze these networks and interactions,

Social Network Analysis (SNA) was used. We have used Ucinet 6 which works in tandem with Netdraw for visualizing networks [18]. For data collection we used a combination of full network method and snowball method [14]. First the list of students that were invited to participate in the research was composed. The respondents were final-year students at the Faculty of Organization and Informatics enrolled in the "Information Systems" course. The students in the sample defined their relationship among themselves, although they were allowed to include students outside the sample as well if their interaction with them was in accordance with survey questions. In that way two data samples were obtained: the original sample consisting of 27 students and the extended sample consisting of 52 students. The response rate was around 40%.

In original sample 3 students are part-time and 24 are full-time students. Further, three students enrolled at the Faculty in 2001, one student in 2003 and 23 students in 2004. The research was conducted in year 2009 and students participated voluntarily. According to number of remaining exams and year of enrollment at the Faculty there are 8 successful students and others are less successful. Finally, there are 12 female students and 15 male students.

Firstly, three networks were composed: social network of teamwork in formal studying, learning materials exchange as well as informal communication among students. According to type of relation that was examined, composed graphs, that is social networks, are undirected graphs. Every node in a social network represents one student and edge represents relation between students. Edge between nodes (students) is present if relation between students exists. There are 27 nodes ($n = 27$) in all composed social networks and the highest possible number of edges is $\frac{n*(n-1)}{2} = 351$.

3.1. Social network of teamwork

Nowadays it is very popular and often justified to use teamwork as a teaching and learning method in formal university education. Teamwork is a form of cooperation where students come in various interactions, such as formal communication, informal communication, as well as fulfilling the tasks and requirements together in order to eventually achieve a common goal. In line with this, we assume that students inclined to this form of cooperation have specific characteristics in common. Based on this assumption, hypothesis 1 is set.

Hypothesis 1: *In a teamwork social network, communicative and extroverted students inclined to teamwork and learning have the highest degree centrality.*

According to our research, the highest degree centrality (9), in the selected sample, is attributed to students number 5 and 7. In this case, degree centrality is observed as number of different students whom with one student worked in team. We know from the accompanying data that students 5 and 7 are less successful students, neither particularly communicative nor extroverted. Further, although they practice teamwork when it is required, they are not especially keen on teamwork. Therefore we could assume that the high degree centrality of the aforementioned students is the result of their easy adjustment to changes and adaptability. However, the fact that they do not necessarily belong to a fixed team can be explained by the fact that teams can be defined by teachers, so students can end up working in different teams.

If we consider the extended network, there were two additional students who have the highest degree centrality: students number 10 and 20. They are communicative and extroverted, inclined to learning in teams, the only difference being that student 10 practices teamwork whenever is possible and student 20 when it is necessary.

As we can see, in the first case hypothesis 1 is not confirmed, but in the second it is, and therefore, according to our rather small sample, we cannot claim that communicative and extroverted students are necessarily inclined to team work and learning in different team environment.

Students 9, 14, 15, 23 and 27 have the lowest degree centrality. Students 9, 14 and 15 are part-time students and mostly cooperate and build teams among themselves, while students 23 and 27 are very communicative and extroverted and prefer teamwork. Their degree centrality is 3, which means that they try to work in a familiar team environment.

Student 24 has the highest betweenness index considering the fact he is the link between two sub-networks: the network of part-time students (9, 14, 15) and the network of full-time students. Student 24 has worked in a team with student 14 and they are cut-points of the teamwork network. We can also say that the edge connecting nodes 24 and 14 is a bridge in this graph since deleting it would cause its endpoints to lie in different components of the graph. Considering that part-time students 9 and 15 have not worked in a team with full-time students, they have the lowest betweenness index. Students' position in the teamwork social network is shown in Figure 1.

Further, students with the highest degree centrality in the teamwork network are closer to other students. Therefore, students 5 and 7, who worked in a team with the biggest number of different students, have a more favorable position owing to their closeness to other students, which means that they can access other students quickly.

As we already mentioned, students 14 and 24 are the cut-points of the network, which explains why the network is divided into three blocks (sub-networks). The first block consists of part-time students, students that are cut-points constitute the second block, whereas the third block consists of the remaining full-time students.

The clustering coefficient [1] [15] is defined as students' inclination and probability to work together in teams. In our case it has the value 0.479.

Further, there are three maximum cliques [6] [12] in the teamwork social network and each of them consists of 5 students:

1: 5 10 13 17 20
2: 5 8 10 20 21
3: 4 5 10 13 17

It should be noted that the characteristic that students forming the third clique have in common is that all of them come from the same county. Further it can be noticed that part-time students form the clique with three nodes.

The diameter of this network is 5 and it represents the geodesic distance between students 9 and 18.

Density of social network of teamwork is 0.2136.

Considering correlations between gender, students' success and their position (degree, betweenness and closeness) in the social network of teamwork there is only one significant correlation found. It is at level 0.05 – correlation between gender and betweenness, which means that male students have better betweenness in the network. But we have to be careful with this conclusion because we have too small sample of female students in our study to justify it.

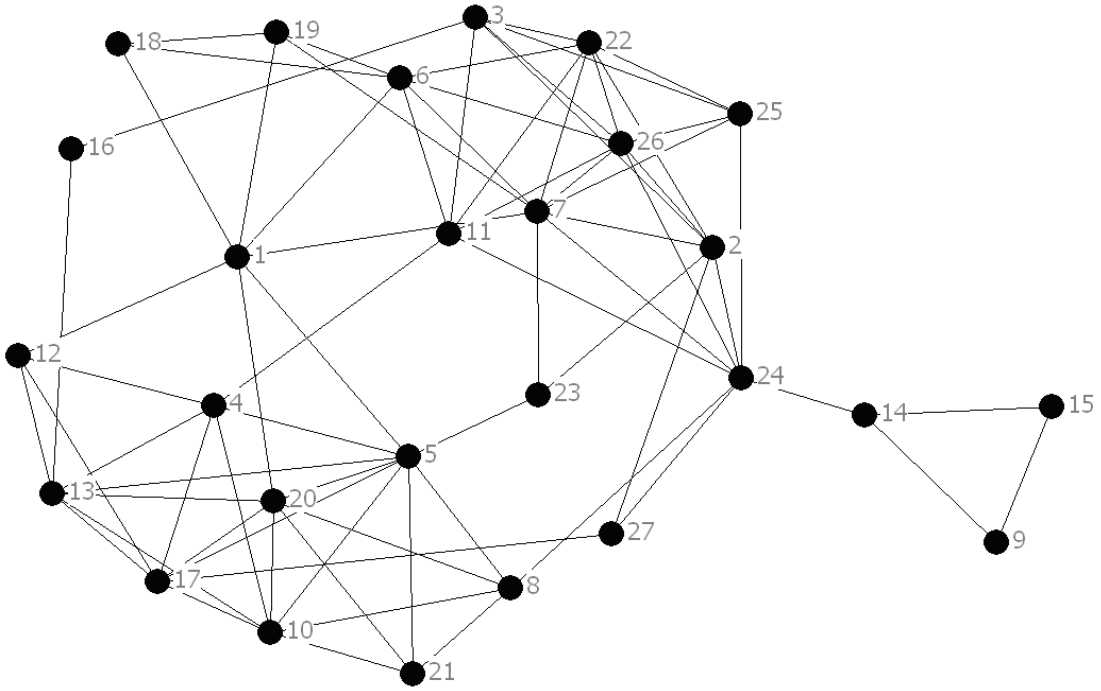

Figure 1. Social network of teamwork

3.2. Social network of exchanging learning materials

All students occasionally participate in the process of exchanging learning materials. We investigated which students are the centers of this social network through centrality measures, also taking into consideration the characteristics of these students. We set the following hypothesis:

Hypothesis 2: *In a social network of exchanging learning materials, successful students who regularly attend classes and who have not used materials prepared by senior students as the main learning material for exams have the highest index of centrality.*

As we can see in the Figure 2, which represents the social network of exchanging learning materials, students 5 and 22 have the highest degree centrality. That means that those students exchanged learning materials with biggest number of other colleagues. While student 22 is successful, student 5 is less so. Both of them consider themselves to be responsible students. Further, they attend lectures and seminars. However, students 5 and 22 differ in the literature they used. Student 5 used the learning materials digested by students from previous years, whereas student 22 prepared his own notes and consulted the materials prescribed for the courses. According to this, hypothesis 2 is only partially confirmed. Considering the high degree centrality of student 22 we concluded that the successful student is distinguished from others and is considered as a source of quality materials. On the other hand, student 5 is obviously very well equipped with learning materials and therefore as many as 17 students recognized him as a source. In [5] authors determined that "some of the most successful students, with extrovert personalities, are the stars of the three networks" and it can be related with results obtained in above analysis.

The above-mentioned students are also central students according to betweenness and closeness centrality. Thus they are in a privileged position in comparison to others and they also have impact on the exchange of learning resources. The fact that they have alternative paths for searching the network looking for materials implies that they are less dependent on others, which can additionally enhance their privileged position. Closeness to others positively influences the speed of obtaining the materials. These students' relative power arises from the fact that students 5 and 22 can interrupt the flow of materials exchange in

which they mediate. In that case other students would be forced to find alternative paths in the social network of learning materials exchange. According to this, we conclude that students 5 and 22 have the biggest control on learning materials exchange. However, student 22 is the center and the authority of this network.

Similar to the teamwork network, part-time students mutually exchange materials, but their interaction with full-time students has also been enhanced. However, the degree centrality of part-time students is the lowest in the whole network. According to betweenness and closeness centrality, their position in the network is not so favorable, which means that they have to invest more effort to obtain the materials.

Some full-time students also have equally unfavorable position according to centrality measures. The degree centrality of student 25 and the betweenness centrality of students 4 and 25 are as low as the degree and betweenness centrality of part-time students, which means that students 4 and 25 do not have any impact on the learning materials exchange process.

The diameter of the exchange of learning material network is 3 and it is equal to the geodesic distance between students 4 and 7. The clustering coefficient, which we interpret as the probability of students' mutually exchange of materials, is 0.572.

According to betweenness centrality, there are three hierarchical levels in the social network of exchanging learning materials. The lowest level consists of students 4, 9, 15 and 25, who do not have any impact on the learning materials exchange process (betweenness centrality: 0). However, part-time student 14 is located on a more favorable – second – level since he interacts with full-time students as well. Other students situated on the third level are full-time students who interact with greater number of students and, in some way, control the exchange of learning materials. There are 10 students located on the third level who are also good hubs and authorities.

The maximal clique of this social network consists of 9 students (third network): 4 5 8 10 13 14 17 20 21.

If we compare the social network of teamwork (Figure 1) to the social network of exchanging learning materials (Figure 2), we can see that the latter is denser than the former. There are 141 realized edges in this social network, so density of social network of exchanging learning material is 0.4017. According to this, we conclude that students enter into a greater number of interactions with other students to obtain necessary materials. In addition, students tend to prefer doing teamwork with the same colleagues.

Additionally we considered correlations between gender, students' success and their position (degree, betweenness, closeness) and in this social network only one significant correlation at 0.05 level is found. It is correlation between students' success and closeness which means that successful students are closer to other students and this conjecture can be researched further.

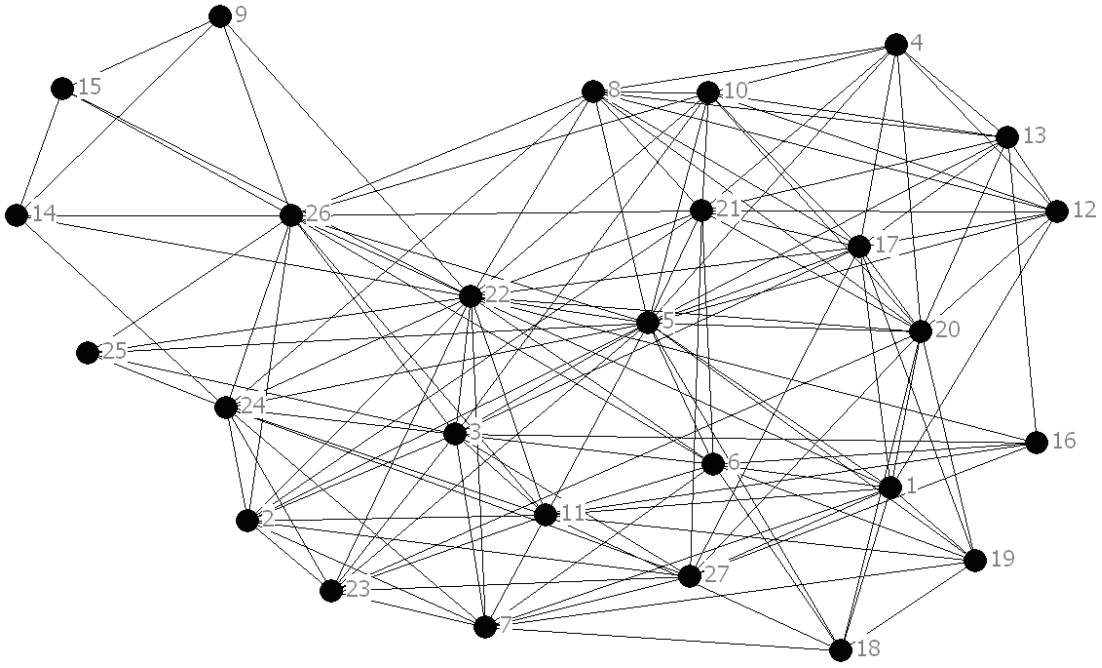

Figure 2. Social network of exchanging learning material

3.3. Social network of informal communication

Informal communication is probably the most common form of interaction and, accordingly, it was expected that this social network will be the most dense of all, with the biggest maximum clique. To our surprise, data show the opposite. The social network of informal communication is not so dense as the social network of exchanging learning materials (density of social network of informal communication is 0.3789) and the maximal clique consists of only 7 students.

Maximal cliques are as follows:

1: 2 3 11 22 23 24 26
2: 2 3 11 22 23 25 26
3: 5 8 10 13 17 20 21

Again, the diameter of this social network is 3 and it is equal to the geodesic distance between students 1 and 14.

Considering that the resource exchanged in this network is information, we assume that students' position in the network depends on their inclination to communication.

Hypothesis 3: *In a social network of informal communication, communicative and extroverted students willing to share information with others have the highest degree centrality.*

In the social network of informal communication (Figure 3) students 11, 22 and 26 have the highest degree centrality. They consider themselves to be communicative, extroverted and willing to share information with others. Considering their characteristics, we assume that they have no problems interacting with others.

Students 11, 22 and 26 also have the most favorable position considering the betweenness and closeness centrality. They are intermediaries in many flows of information and act as hubs, while being authorities in the social network of exchanging learning materials. Therefore, they are very likely to be informed about the events in the network. Whereas closeness to the other students allows them to be quickly informed, high betweenness allows them to control information flow.

Although there is no hierarchy in the social network of informal communication, we would emphasize these students as having a favorable position in the network in comparison with others. Part-time students, even if they are communicative and extroverted, have again proved to have the lowest degree centrality. They mostly communicate between themselves. Student 1 is extroverted and communicative but his degree centrality is the lowest so we assume that he either prefers staying within a fixed group of peers or he overestimated his communication abilities. As we can see, in our case the degree centrality does not depend on students' extroversion and communication abilities but rather on their tendency to interact with others.

Part-time students as well as students 4 and 25 again have the lowest betweenness centrality. Students 4 and 25 also have the lowest degree centrality in the social network of exchange of learning materials, which confirms the fact that students are not keen on interacting with many different students and therefore do not have impact on information flow in the network. Owing to their distance from the full-time students, part-time students 9 and 14, as well as full-time students 4 and 12, need the longest time span to get certain information.

According to betweenness centrality, there is only one level in the social network of informal communication. That is in line with our expectations, since the exchange resource has no influence on academic success.

The clustering coefficient, which represents the probability that students will be informed about network events as well as their tendency to informal communication, is 0.531.

As we have already mentioned, the social network of informal communication is not so dense as the social network of exchanging learning materials, which means that students interact with a greater number of colleagues if they can benefit from these interactions.

It is interesting that in social network of informal communication, students' success correlates with all centrality measures (degree, betweenness and closeness) so successful students have better position in this network. We did not foresee this result and it can be used as a hypothesis for further research.

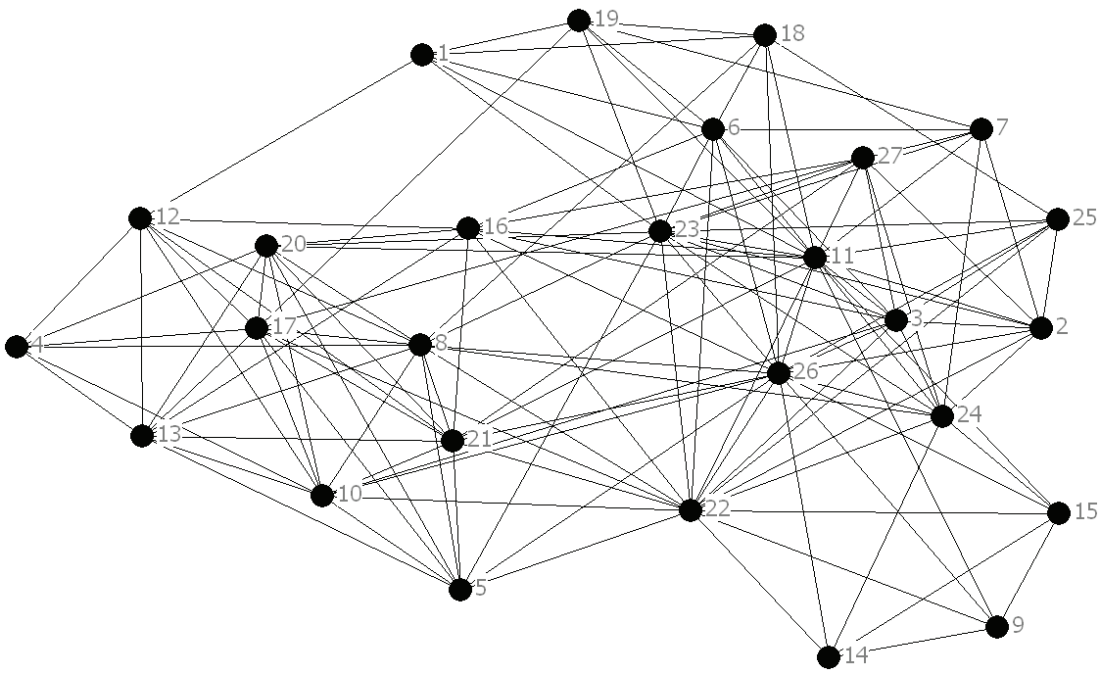

Figure 3. Social network of informal communication

3.4. Basic social network of students' position in study environment

The basic social network of students' position in study environment is the common intersection of all three social networks: social network of team work, social network of exchanging learning materials and social network of informal communication. Resulted structure is mathematical graph shown in Figure 4.

Observed interactions between students are typical for study environment and probably the most often, so this social network can be considered as a basis of students networking since the nodes in this student network are connected by edges with weight equal 3.
Present interactions between students are constant and ongoing and they do not depend on a type of students' activity.

The total number of realized edges is 66, so the density of this social network, is 0.1880. As we can expect from the construction, the basic social network is the rarest of all considered networks.
There are 16 cliques of size 3 or bigger present in this network and maximal clique consists of 5 students. Students in these cliques are very well bounded.

If we consider students' position in basic social network through centrality measures, there are three central students. Students 5 and 26 have the highest degree centrality (8). The highest betweenness centrality has student 24 who is also cut-point in this network. Student 24 is the mediator between part-time and full-time students. Student 26 is the closeness to other students. Students 24 and 26 are extroverted and communicative students. Again, we can confirm conjecture that extroverted and communicative students have good position in a student network. Students' success and gender do not correlate with position in this social network.

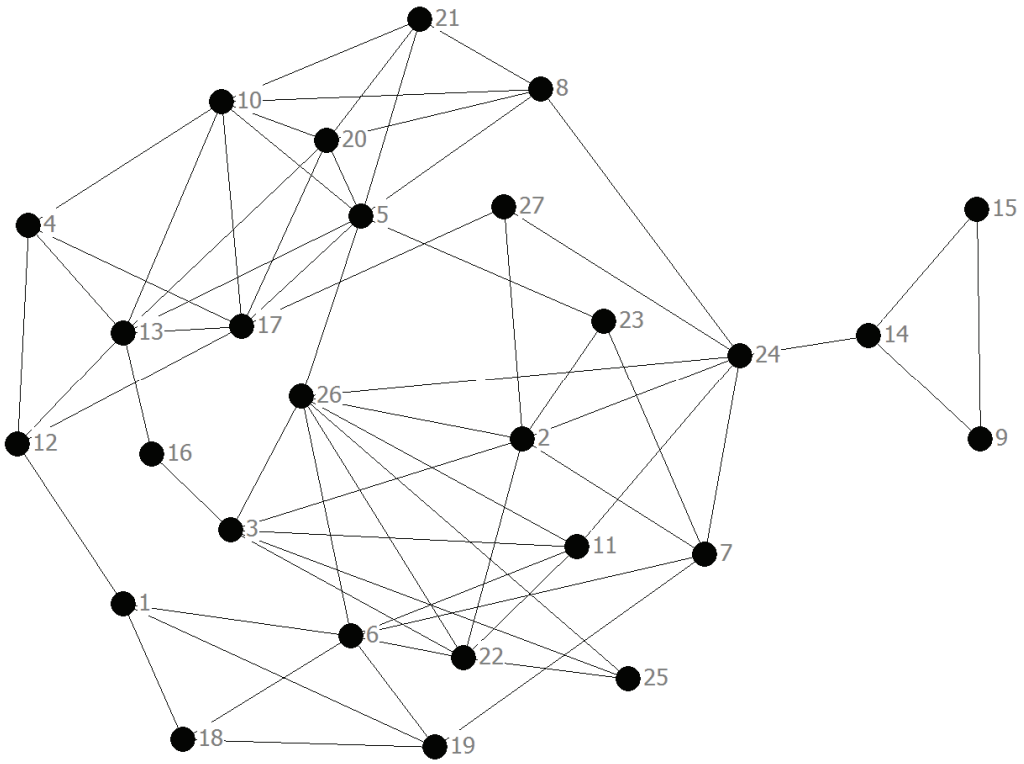

Figure 4. Basic social network of students' position in study environment

3.5. Aggregated social network of students' position in study environment

Aggregated social network of students' position in study environment is union of social network of team work, social network of exchanging learning materials and social network of informal communication. We used software tool Pajek in order to visualize and analyze the

obtained network [17] and in order to get the union of the three networks. Resulting graph is shown in Figure 5.

Total number of realized edges is 165 out of possible 351, so density of this aggregate social network is 0.4700. We can see that this social network is 2.5 times denser than basic social network. There are 50 cliques size of 3 or bigger in this social network which is 3 times more than in the basic social network. The maximal clique consists of 9 students and there are three such cliques.

The highest degree centrality in the aggregated social network have students 5, 11 and 22. The highest degree centrality is 20, that is 2.5 times more than the highest degree centrality in basic social network. The highest betweenness centrality have student 22 while the most closeness to other students are students 22, 11 and 5. We can notice that only student number 5 occurs in both basic and aggregated network with good centrality position.

If we observe correlations between gender, students' success and their position (degree, betweennes and closeness) in the aggregated social network, there are significant correlations between success and degree, betwenneess and closeness centrality in this network. Correlations are represented in Table 1.

Comparing this result with results obtained in social network of teamwork, social network of exchanging learning materials and social network of informal communication, we can conclude that students' success is a prominent predictor on a global level. For the further research it will be intriguing to investigate aggregated networks and predictors of centrality positions in them.

	Degree	Betweenness	Closeness
Gender	-0.006	0.050	0.035
Success	0.442*	0.454*	-0.455*

Table 1. Correlations between gender, students' success and centrality measures in aggregated social network of students' position in study environment

* Correlation is significant at 0.05 level

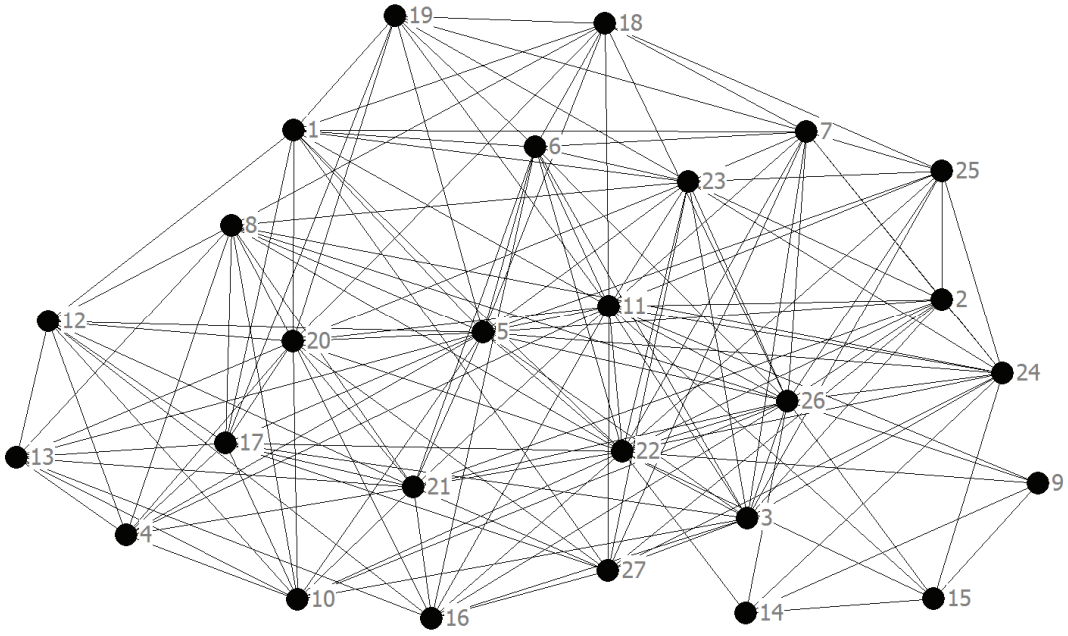

Figure 5. Aggregated social network of students' position in study environment

4. Conclusion

In our pilot research there are two data samples: in the basic sample N=27 and in the extended sample N=52. In the basic sample only 8 students can be considered successful, whereas the others are not so successful. Although we are aware that the sample is rather small, this exercise has been performed as a pilot research in order to set certain hypotheses for future research and to investigate the notion of "study environment". The first question we investigated is whether there is a correlation between students' academic success and their position in a social network. The main result is that the position in a social network cannot be forecast by academic success only. Nevertheless, successful students tend to have a rather good position in social networks. There are other characteristics that define students' position in such networks. For example, in case of the network of exchanging learning materials, students that are responsible and attend classes regularly are better positioned. Further, in the network of informal communication, communicative and extroverted students willing to share information with others have the highest degree of centrality.

If we compare the social network of teamwork with the social network of exchanging learning materials, we can see that the social network of exchanging learning materials is denser than the first one. Accordingly, we can conclude that, when learning materials are concerned, students enter into a greater number of interactions with other students to obtain the necessary materials. On the other hand, in teamwork students tend to prefer working with the same colleagues. Further, the social network of informal communication is not as dense as that of exchanging learning materials, with maximal cliques smaller than those in the social network of exchanging learning materials. In the two social networks that represent relationships associated with academic achievement there exists a hierarchical structure. On the contrary, in the social network of informal communication, which is not directly associated with academic achievement, there is no hierarchy. Finally, it is obvious that part-time students formed separate groups that are poorly connected with full-time students. The degree centrality of part-time students is the lowest in the whole network. Since their academic performance is generally weaker than that of full-time students, this fact can be considered as an obstacle for them to pursue their studying in an orderly manner.

In the end, it is important to mention that clustering of survey participants was also conducted for all social networks but clusters were not significant. Further research in this direction will be done.

Further, aggregated network gives us useful global perspective of student position in a learning environment as well as good grounds for formulation conjunctions to be investigated further. First of all, interesting problem is to find out possible components that form aggregated network. Then it will be useful to confirm predictors of centrality positions in aggregated networks. Further research has to be conducted on a bigger sample and it may examine if there is any correlation between gender and a centrality position in the network. Finally, at the end of each subsection in the section 3, we formulated interesting conjectures for further research for which we hope our presented results can serve as a useful pilot investigation.

References

[1] Barabasi, A.L; Jeong, H; Neda Z; Ravasz, E; Schubert, A; Vicsek, T. Evolution of the social network of scientific collaborations. *Physica A*, pages 560-614, 2002.

[2] Boulet, R; Jouve, B; Rossi, F; Villa, N. Batch kernel SOM and related Laplacian methods for social network analysis. *Neurocomputing* 71, pages 1257-1273, 2008.

[3] Busato, V.V; Prins, F.J; Elshout, J.J; Hamaker, C. Intelectual ability, learning style, personality, achievement motivation and academic success of psychology students in higher education. *Personality and Individual Differences,* Volume 29, pages 1057-1068, 2000.

[4] Cho, H; Gay, G; Davidson, B; Ingraffea, A. Social networks, communication styles, and learning performance in a CSCL community. *Computers & Education,* Volume 49, pages 309-329, 2007.

[5] Hamulic, I; Bijelic, N. Social network analysis in virtual learning community at faculty of information technology. *Procedia Social and Behavioral Sciences*, pages 2269-2273, 2009.

[6] Jamali, M; Abolhassani H. Different aspect of social network analysis. *Web Intelligence, 2006. WI 2006. IEEE/WIC/ACM International Conference*, pages 66-72, 2006.

[7] Knight, P.; Yorke, M. *Learning, Curriculum and Employability in Higher Education.* RoutledgeFalmer, London, 2004.

[8] Martinez, A.; Dimitriadis, Y.; Rubia, B.; Gomez, E.; de la Fuente, P. Combining qualitative evaluation and social network analysis for the study of classroom social interactions. *Computers & Education,* Volume 41, pages 353-368, 2003.

[9] Newman, M.E.J. Who is the best connected scientist? A study of scientific coauthorship networks. Notes in Physics, Volume 650, pages 337-370, Berlin, 2004.

[10] Ramirez Ortiz, M.G.; Caballero Hoyos, J.R.; Ramirez Lopez, M.G. The social networks of academic performance in a student context of poverty in Mexico. *Social Networks*, Volume 26, Issue 2, pages 175-188, 2004.

[11] Ramsden, P. *Learning to Teach in Higher Education.* RoutledgeFalmer, 2005.

[12] Wasserman, S; Faust, K. *Social Network Analysis: Methods and Applications*. New York, Cambridge University Press, 1994.

[13] Yang, H.; Tang, J. Team structure and team performance in IS development: a social network perspective. *Information & Management*, Volume 41, Issue 3, pages 335-349, 2004.

[14] Hanneman, R.A; Riddle, M. Introduction to social network methods, http://www.faculty.ucr.edu, downloaded: 22th March 2009.

[15] Hoppe, B. Introduction to Network Mathematics, http://webmathematics.net/, downloaded: 22th March 2009.

[16] Krebs, V. Social network analysis, 2008. http://www.orgnet.com/sna.html, downloaded: 27th March 2009.

[17] Pajek Wiki. http://pajek.imfm.si/doku.php, downloaded: 25th January 2009.

[18] UCINET. http://www.analytictech.com/downloaduc6.htm, downloaded: 25th January 2009.

[19] Wikipedia, Social network. http://en.wikipedia.org/wiki/Social_network, downloaded: 29th March 2009.