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A Study of Characteristics of Social and Learning Networks of Civil Engineering Students

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Abstract—**The features of the geological backgrounds of the civil engineering students of National Quemoy University Taiwan, create a morphology similar to that of a melting pot. Since other universities have limited social interactions with the students in Kinmen, the social life of the students can only be confined on the island so that the students form an ideal isolated population for social network study. This research explores the relationship between the academic performances and the social behaviors as well as the social and learning networks of 179 students of the Department of Civil and Engineering Management at the university. What is found is that the social networks do not become fragmented, but the number of cliques decreases for senior classes. This research depicts that living together during freshman year can be the most decisive factor, followed by participating in clubs and genders, in shaping students' social lives within the next 3 years. The highly consistent performances in grades and attendance of clique members compared to the average of the entire class confirm the inevitable peer influence within the cliques. This research is a pilot study of applying network theorems on analyzing engineering student social networks so that the results can be utilized to devise student counseling and to improve the quality of teaching..**

***Keywords*—College Students, Clique, Kinmen, Social Network.**

I. Introduction

A university is the professional incubator for college students. Most professors are focused on research or experts in some technical areas but do not excel in student counseling. Professors always overlook the lifestyle of college students, and lack interest in really getting to know their students well. This sometimes makes it hard for them to improve their quality of teaching. Without student counseling, the relationship between students and professors would be alienated and the student's learning efficiency may therefore decrease. This phenomenon commonly exists in most universities in the world. It is the mission of engineering teachers to improve not only the quality of teaching, but also student counseling.

College students are a unique population in a society. Their daily life is mostly confined to the school and their dormitory, therefore their living and learning habits are strongly influenced by their peer students. We suspect that the social network location of a student may decide his or her academic performance. Although there are many facets for student counseling, some scientific methods may be utilized to resolve some student problems. The so-called social network analysis is a powerful potential tool to evaluate the characteristics of a college student's interpersonal and learning networks, and to unearth the underlying factors that influence their learning efficiency. It is the objective of this research to explore the possible applications of social network technology on depicting the implications of students' social networks on their social relationships and academic performances.

Interpersonal relationships are the most troublesome issue in student counseling [1] but universities often overlook it. The time spent in college is not only the first but also a critical stage of developing one's serious social relationship [2]. A distant interpersonal relationship is one of the causes of learning deficiency [3] because social relationships may not only affect the habits to daily life but also change the attitude to learn. Furthermore, highly interactive relationships among students would display more satisfaction to their school [4]. Social relationships among students are not only a student issue, but an important issue in managing a university. It should not be so easily overlooked.

Four years of college laying the foundation of professional abilities is one of the turning points of one's live. However, many students actually waste time on worthless activities during the four years without academic or professional achievements. On the other hand, peer friendship can provide emotional and social supports, mature interpersonal relationships and shape self esteem [5]. Especially, having more friends in freshman year can ease students into college living in the following year, but having conflicts with friends is difficult to resolve and can cause a lowering learning efficiency [6]. But the encouragement of a close friend or a circle of friends can mitigate this with similar interests or personalities. Living in the same dormitory during the first year in the school helps develop most friendships of college students. Living together in one's first year has great influence on the formation of a student's social networks and further on the life in the rest of the college years. For college administrators, it is significant to observe and to analyze the social networks of students because the networks may be decisive to a student's personality development and to the performance of the school.

Network science has been developed for 17 years [7] [8]. The broad applications have been demonstrated in the areas such as transportation networks [9][10], electric power grids [11][8], international trade [12], World Wide Web and Internet [13][14], disease transmission [15], organized crimes [16] [17], counter terrorism [18], political analysis [19] and even cancer research [20]. But the most important application is on the social networks. Even so, the research

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of school social networks is not common. There are studies trying to analyze the segregation of race in social networks [21]. It was found that there is high correlation between GPA and network position [22].

To find out the effects of social networks on students' learning and life, we select a university in Taiwan to be a case study. A network is connected by nodes and links. In social network, an individual is a node and the relation between two individuals is a link. This link can be directional or non-directional depending on the nature of the relation. Three aspects about network architecture needed to be addressed which are entire network topology, subnetwork composition, and individual functions. The dynamics of the topology of a social network is based on the activities of nodes or groups of nodes especially those nodes that are in the critical position in the network. To identify the importance of a node, some network indices such as degree centrality, eigenvector centrality, closeness centrality and betweenness centrality, have been developed. Each index plays a distinct role with special meaning in information transmission among nodes in the network. The subnetworks can be independent networks, cliques, and components. It is important to unearth the underlying factors that drive nodes to form subnetworks since congregation of individual nodes form subnetworks and integration of subnetworks shapes the entire network. How the topology, causes of formation, and the mechanism of formation of student social networks change the students learning efficiency and living habits, may be the central issue for the university and the department to exploit and to use to improve teaching and counseling.

The case of this research is the students of the Department of Civil Engineering and Engineering Management of National Quemoy University in Taiwan. The department has one class for each year and 179 students were surveyed for the questionnaire. This research focuses on the following five subjects:

1. The evolutions of social network topology: The changes of student social networks will demonstrate the closeness of student relationships and may also reveal the causes of the evolution.

2. The formation and effects of social cliques: A student may belong to one or several social cliques. Based on the students' habits or the special features of cliques, one may conclude the factors that affect a students' performances.

3. The influence of the position in social networks: In some social networks, individuals with specific network positions may display great influences on network architecture especially in resource acquisition and information control. It is critical for counseling staff to identify those individuals.

4. The discrepancy between friendship and learning networks: College student activities are important in daily life and learning. The discrepancy between the two networks may provide information about the factors that affect the student's willingness to learn.

5. The manifestation of student attributes in the social networks: Student attributes such as sex, GPA, origin, class attendance, may be the decisive factors in how they locate in the social networks. It may be of interest to clarify these correlations.

To answer the above questions, questionnaires were conducted for the four classes to construct the friendship and learning networks. UCINET, a social network analysis software, was utilized to analyze the network indices and Netdraw, a graphic software, was used to draw the sociograms. The various network indices can manifest the causes and implications of student networks.

II Method

This study employs social network analysis methods to develop the learning and social networks of civil engineering students with the data from direct surveying. The students of four classes of Department of Civil and Engineering Management were asked to provide the surveyors with a list of their learning partners and social friends in their classes. For the first questionnaire, a surveyor gave each student a list of classmates of their class and asked each student to pick his/her good friends of who were defined as at least 4-5 hours of gathering in a week. After recovering the first questionnaire, the surveyor gave each student the same list again and asked each student to pick his/her learning partners. Surveys were conducted on a Free Choice basis to prevent possible information loss. Once some irregular questionnaires were discovered, the surveyor would ask the student to correct or repack to filter the possible errors. The researchers also obtained the academic performance data and attendance information with the help from the university. Once all the questionnaire and personal data were completed, some arrangement of data is needed. By the nature of the survey, the social relations are essentially directional, and therefore, the one-way relations in learning and social network had to be symmetrized before further analysis. The questionnaire produces directional networks such as A giving orders to B and B giving orders to C yielding A→B→C directional links. The three networks are all directional but they can be transformed into non-directional networks using maximal or minimal symmetrization. For maximum symmetrization, one way or reciprocal links are all treated as mutual links. In minimum symmetrization only reciprocal links are considered effective. Both symmetrization formats generate non-directional links such that the calculation will be much simpler and the network topology will be clarified. Once the questionnaires were all collected, Excel data files were filled and UCINET, social network software, was used to calculate the various indices. With the help of NetDraw, network drawing software, network sociogram visualization was available as shown in Figs.1-8.

III Results and Analysis

The backgrounds of students are shown in Table 1 which lists the number of student, ratio of female and male students, and origin of students (North/Central/South/East/Local, N,C,S,E of Taiwan, Local is Kinmen). The number of students decreased because some students either dropped out or transferred to another university so that the networks were restructured. The original friendship and learning networks with directional

relationship for each year are shown in figures 1-8. Observing the sociograms, for friendship networks, it can be found that the networks are much broader and closer in freshman and junior years than sophomore and senior years. The students in learning networks are basically much more dispersed than the friendship networks. Some students prefer to study alone without forming learning clusters and one independent subnetwork (component) with 5 students formed in junior year. The average degree and number of clique of friendship and learning networks were calculated by UCINET and are showed in Table 2 and 3, respectively. Due to the difference in the number of studens for each year, it is inadequate to make a comparison based on absolute data therefore "normalization" is needed to overcome this problem. The benchmark of student number is set to be 50 then the normalized indices $\overline{S}$ (degree and number of clique) is recalculated as

$$\overline{S} = S \cdot \frac{50}{n},$$

where S is the original index and n is the original number of students. After normalization, the trend of degree mentioned above disappeared but learning networks is still much more fragmented than friendship networks. One of important subnetworks in network analysis is clique which is defined as in a group of node, each node has a link with every other node in the group and which is the most closed relation in a network. The basic clique is for 3 nodes (Figure 9a). The 4-node clique is shown in Figure 9b. This research analyzes the number of clique for each year based on a 3-node clique. The number of cliques also implies the closeness of the networks. Except for senior year, the distribution of number of cliques is quite consistent between friendship and learning networks. It can be noted that there is only one clique in the learning network of senior year, which means there is almost no group learning mechanism in the last year for this class.

Table 1 List of student background

Year	number of student	Female/Male	Origin
1	51	10/41	21/7/14/1/8
2	49	12/37	15/11/16/1/6
3	43	14/29	13/6/22/0/2
4	36	9/27	7/8/17/1/3

Table 2 List of student average degree

Year	Average degree of friendship network		Average degree of learning network	
	Original	Normalized	Original	Normalized
1	9.706	9.516	2.922	2.865
2	6.367	6.497	3.224	3.290
3	6.977	8.113	2.698	3.137
4	5.944	8.256	2.028	2.817

Table 3 List of number of cliques

Year	Friendship network		Learning network	
	Original	Normalized	Original	Normalized
1	45	44.117	7	6.863
2	20	20.408	3	3.061
3	24	27.907	5	5.814
4	17	23.611	1	1.389

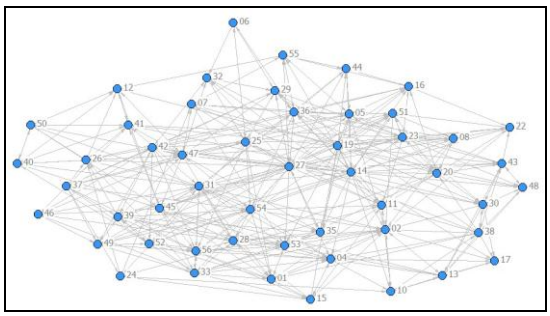


Figure 1 Friendship network of the freshman class

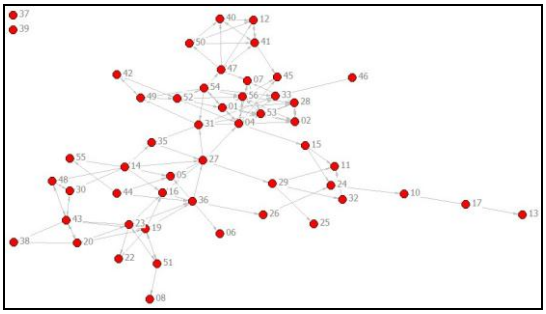


Figure 2 Learning network of the freshman class

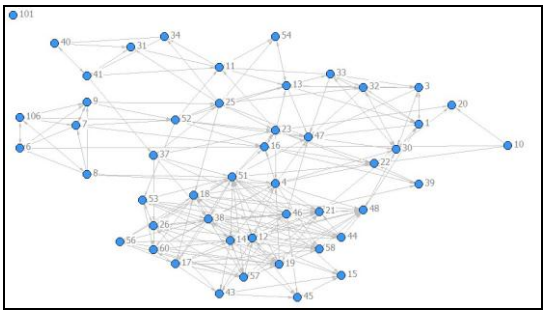


Figure 3 Friendship network of the sophomore class

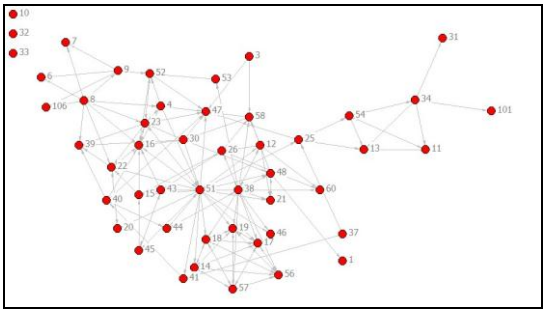


Figure 4 Learning network of the sophomore class

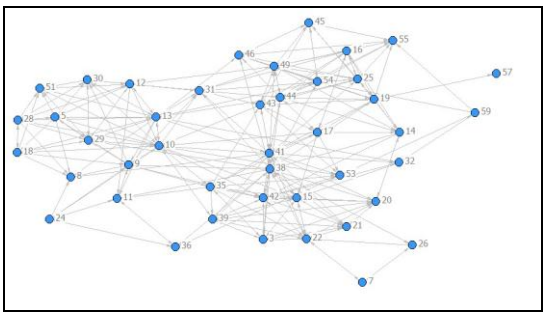


Figure 5 Friendship network of the junior class

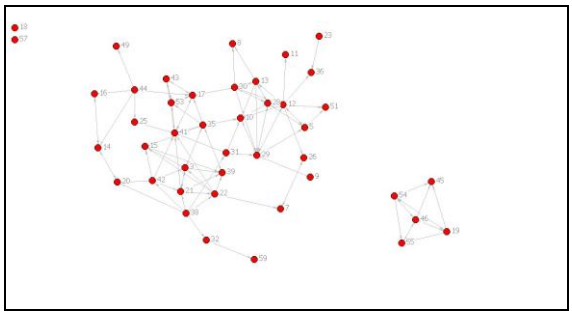


Figure 6 Learning network of the junior class

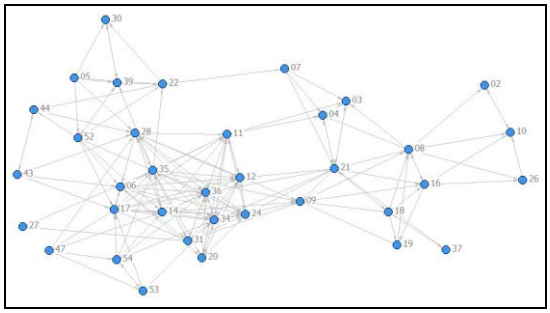


Figure 7 Friendship network of the senior class

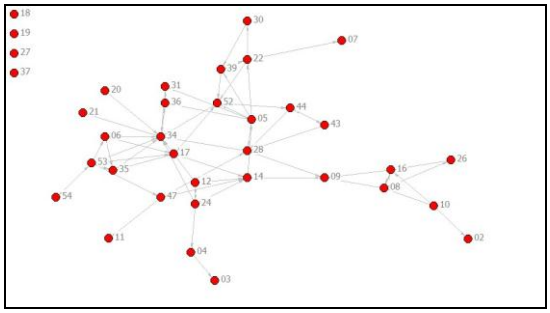
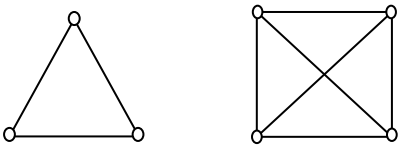


Figure 8 Learning network of the senior class



a. 3-node clique b.4-node clique

Figure 9 Illustration of 3-node and 4-node clique

The original relationship between two students is directional which may cause complications in the network index calculation and may misrepresent the real relationship because some students may over estimate his/her popularity and pick too many friends or learning partners. To mitigate these extreme cases, minimum symmetrization was implemented to remove all unidirectional links but keep reciprocal links only. The average degree and number of clique of the symmetrized networks are listed in Table 4 and 5 and the sociograms of friendship and learning networks are shown in Figure 10-17. The average degree of friendships and learning networks are about 60% and 50% of original ones. It can be observed that more isolated individuals and components appeared in both networks and that highly fragmented learning networks. The freshman class not only has a higher degree of and a larger number of cliques but also remains a single network without fragmentation or isolated individuals hence we may able to be suggest that the class has closer relationship than other classes. On the other hand, students in the freshman class were trying to get to know each other therefore a closed social network would be established. Once students better know their classmates, they would select good friends and maintain the relationship, but the number of good friend cannot be too large because students have limited resources or time to invest in the friendship. Junior and senior classes show more components and isolated individuals in friendship networks. We may refer to those college students as becoming isolated or fragmented into small groups. Those small groups connected to each other with "weak links" to form loose giant networks.

A. Individual aspect

Nodes with a high degree of centrality or a high eigenvector centrality are always the most important individuals in a network. Degree represents the number of links a student has and an eigenvector depicts how important the node itself and its adjacent nodes are. This study also calculated the two friendship network indices for each class as known in Table 6 and the results showed that the high degree centrality students who also have high eigenvector centrality. Those students can be identified as popular individuals who occupy the centers of their networks and are critical to the integrality of the entire network. The friendship would be restructured once they were removed. These isolated individuals or cliques should be more closely monitored or constantly contacted for all kind of possibilities.

B. Subnetworks

Subnetworks such as isolated individuals, cliques, or components are always in the state of restructuring. The state of networks is the exact moment when data was collected. The networks and subnetworks of each class is in the process of evolution according to the time therefore we are analyzing the subnetworks at the time of surveying. There are 122 cliques in original friendship and learning networks of the four classes. The number of cliques decreases for more senior classes. It means that students are more and more isolated with fewer and fewer close friends. We can say that this result is highly related to the curriculums because there are very few courses in senior class such that senior students spends less time in the school;

as a result, less gathering leads students to become estranged. Similar results can be found in learning networks.

The formation mechanism of a clique is an important issue. After the surveying and initial network analysis, some cliques were found for each class. The surveyor interviewed a few students to get to know the reasons students are get together. The causes of congregation are listed in Table 7. Living together (roommate) is the chief cause for students to be close friends and it shares 59.8% of all causes. Roommates of freshman year can be decisive to the formation of friendship circles in the next 4 years. They can even be good friends for life. Participating in school clubs and female partners are the second and third major reasons of becoming good friends. Off class activities and volunteering are the cores to a university [23] because they provide unofficial but interesting opportunities to foster friendship [21].

As unidirectional links minimum symmetrized and removed from the network, some students were then isolated to become independent individuals. These peripheral students may further leave the giant network in ~~the~~ real life and they are the foci in student counseling. A student counsel can provide the results of social network analysis to those potential peripheral or isolated students and explain their position and function in a network [24] and encourage them to rejoin the network to prevent themselves from being too isolated.

One of the most important findings of this research is the high consistence of academic performance and class attendance of clique members. The researchers collected the GPA and attendance records for each student and calculated the standard deviations of GPA and attendance for each student. Comparing the standard deviations between entire class and cliques are shown in Table 8. It can be found that for each class, the standard deviations of average of cliques are smaller than the average of the entire class with regards to GPA and attendance. The consistency of class attendance is the most obvious. We may suggest that peer influence is the most important factor affecting student-learning attitudes.

C. Giant networks

For a network with more than 20 nodes, it is very difficult to evaluate its properties by observation. Network indices must be calculated numerically by computer such that the topology can be well identified. The case of student friendship networks in Kinmen, with the help of calculated average degree and number of cliques, the networks show more components or isolated students for senior classes. More senior students formed small cliques and demonstrated more personality independence but less intimacy. As a result, some weak links were created to connect different cliques such as 23-51, 30-48 for sophomore class (Fig. 12) and 12-44, 10-35, 10-39 for junior class (Fig. 14). Feeling and trust are the foundation of forming a clique but a clique relies on weak links to connect to other groups to build a network [25] such that the information or sentiment among the network can be shared. Comparing directional and non-directional friendship networks, some unidirectional links may be very important in terms of connectivity of a network. Once those unidirectional links managed to become bi-directional links, the connectivity of a network would be improved greatly and some isolated nodes could be rejoined to the giant network. Therefore, good student counseling should strengthen some critical unidirectional links.

Regarding learning networks, it would be very easy to say that learning networks show a much more fragmented nature compared to the friendship networks. The main causes may be threefold: (1) students spend less time studying, (2) many students prefer to study alone, and (3) the department does not provide courses that encourage group learning. On the other hand, for learning efficiency, the size of the group cannot be too large otherwise it is hard for students to concentrate on studying. Based on the author's experience, a group of 3-5 memebers should be an ideal size for effective learning and ~~this~~ is the size for most of student academic competitions. For the current case, among a total 16 learning cliques, 15 groups are in this size; only one clique in the sophomore class has 6 students. Obviously, this is a natural result of learning partner selection and network evolution. Because of the clique size limitation, learning networks exhibit natural fragmentation.

The efficiency of transmission of feeling or information of spread of feeling in a network depends of its topology. The right hand side of Figure 18, the relationship between the number of links and the corresponding number of students in friendship networks fits well with the power law curve which implies "Rich gets richer" [26]. This kind of right skewed degree distribution is typical power law (or scale-free) morphology [27]. The topology of student networks is scale-free like a structure with several features. One of them is that a few hubs (popular students) have more connections but most students are with only limited connections. Once those hubs are removed, the whole network may become fragmented into several components. The friendship among students needs to be rebuilt or restructured. But removal of ordinary nodes may not affect the topology of a network. It implies that in the social network, the status of every participant is not equal. The department or student counselors may need to focus on those hubs and encourage them to display positive attitudes and to become some role models to the other students.

Table 4 Average degree of networks after symmetrization

Year	Average degree of friendship network		Average degree of learning network	
	Original	Normalized	Original	Normalized
1	6.000	5.882	1.725	1.691
2	3.837	3.915	1.429	1.458
3	4.186	4.867	1.441	1.676
4	4.111	5.710	0.833	1.157

Table 5 Number of cliques after symmetrization

Year	Friendship network		Learning network	
	Original	Normalized	Original	Normalized
1	45	44.117	7	6.863
2	20	20.408	3	3.061
3	24	27.907	5	5.814

4	17	23.611	1	1.389

Table 6 List of the student with highest degree and eigenvector centrality

Year	1	2	3	4
Degree Centrality	56>31=36	19=38	10>15=22=41	34
Eigenvector Centrality	31>56	19>38	15>21	34

Note: A>B denotes the index of A is higher than B or A is more important than B.

Table 7 The reasons to form student cliques

Reason	Results										Total
	Freshman		Sophomore		Junior		Senior		subtotal		
	F*	L*	F	L	F	L	F	L	F	L	
Roommate	22	5	9	1	22	2	12	-	65	8	73
Clubs	3	2	11	1	1	-	-	-	15	3	18
Female	3	1	2	-	8	2	2	-	15	3	18
Local Students	9	-	2	1	-	-	-	-	11	1	12
Playmate	9	1	-	-	-	-	1	-	10	1	11
Romance	1	-	-	-	3	1	3	-	7	1	8
Same high school	-	-	2	1	2	1	-	-	4	2	6
Participating Research	2	1	-	-	-	-	1	-	2	1	3
Course Project	-	-	-	-	-	-	1	1	1	1	2
Unclear	3	-	1	-	1	-	1	-	6	-	6

*F: Friendship network, L:Learning network

Table 8 The average standard deviations of GPA and attendance

Items	GPA				Attendance			
Year	1	2	3	4	1	2	3	4
Clique	7.72	4.16	7.74	10.28	12.44	3.23	7.45	7.93
Whole class	9.68	7.94	8.93	11.96	17.71	6.72	11.10	13.68

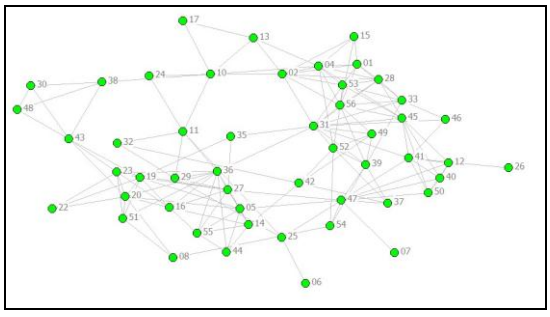


Figure 10 Friendship network of the freshman class after symmetrization

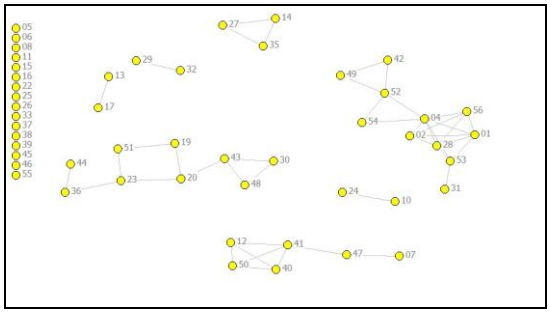


Figure 11 Learning network of the freshman class after symmetrization

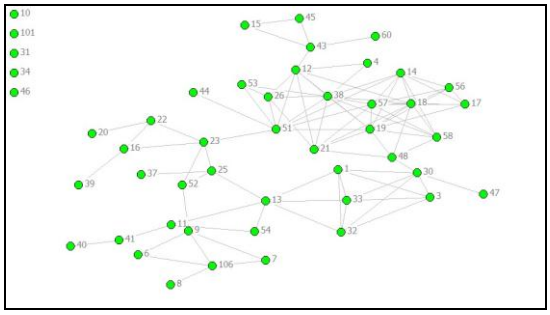


Figure 12 Friendship network of the sophomore class after symmetrization

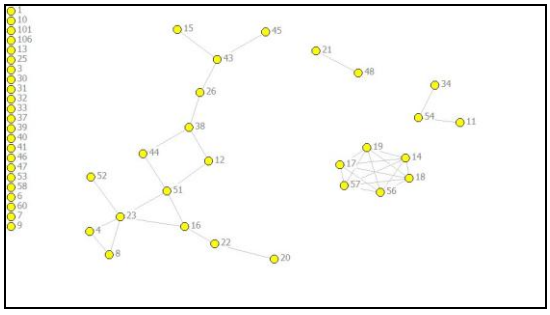


Figure 13 Learning network of the sophomore class after symmetrization

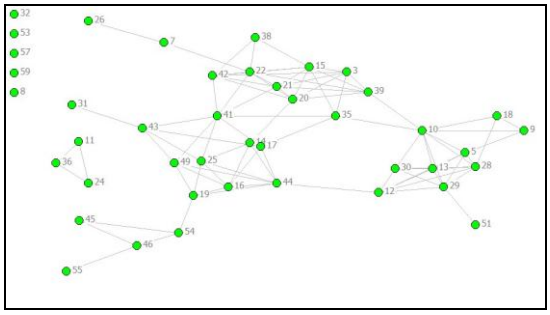


Figure 14 Friendship network of the junior class after symmetrization

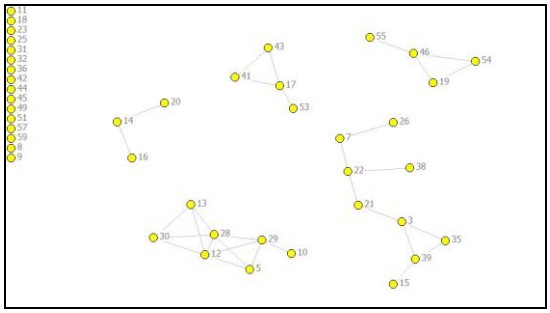


Figure 15 Learning network of the junior class after symmetrization

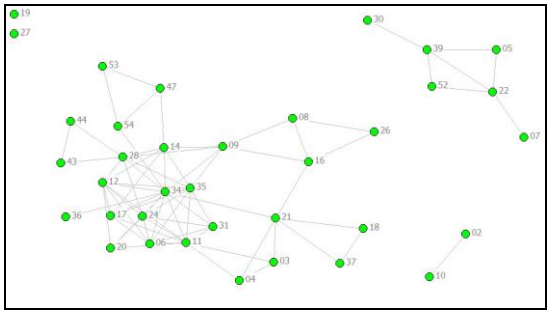


Figure 16 Friendship network of the senior class after symmetrization

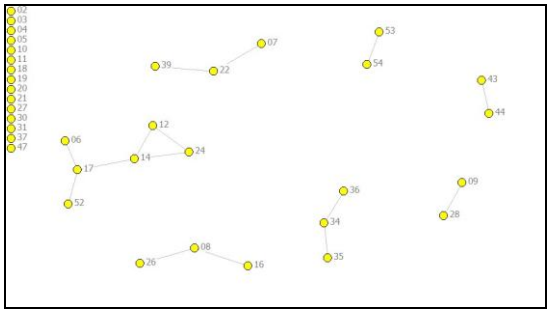


Figure 14 Learning network of the senior class after symmetrization

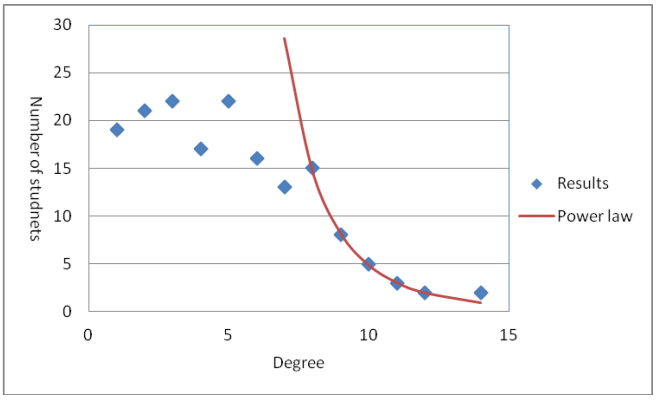


Figure 18 Relationship between degree and number of students

IV Conclusion and Discussion

Students of four civil engineering classes in Kinmen, Taiwan were surveyed for the building of their friendship and learning networks. This research tries to explain the characteristics of engineering student social networks and aims to improve the tactical policies for student counseling. Some interesting results were found such as that the structure of learning networks are more fragmented than that of friendship networks for each class. The friendship networks do not become fragmentary, even though the number of subgroups decreases for senior classes. In comparison with the entire class, students of a subgroup have more consistent academic performances and higher attendance rates. This confirms the positive peer influence exerted by the subgroup. The causes of formation of student social subgroups are, in this order, sharing dormitory rooms during freshman year, participating in the same clubs, having the same gender identification, and living in the same geographic factors. This finding tells us that the freshman year can be a predictor for students' social life for the next three years. For those students isolated from social networks, they were consulted and encouraged to join the networks. Generally speaking, for senior-year students, social and learning networks tend to be more dispersed and relationships are more fragmentary. The students' relationships seem to become closer within their own subgroups, but the number of subgroups drops. Student social circles are shrinking as they enter senior years. This phenomenon may be due to: (1) Frictions among members leading to subgroup dissolution. (2) Lack of frequent interaction among members resulting to the separation from the subgroup. (3) The long-term imbalance of friendships causing relationships to turn sour. A great amount of time and resources are needed to keep each friendship intact, but for college students, they may not have that luxury to invest too much energy on broad relationships. One of the most urgent tasks for the college consultation division is to integrate the isolated students back into social networks because they may be potential problems to our society.

This research may be able to find answers of the five issues raised in the beginning of this paper.

1. The evolution of social network topology: Without considering isolated individuals, the components seem to increase along with year in normalized friendship networks. The average degrees of the learning networks are much lower than the friendship network for each class, especially for senior classes. This is because there are less required courses, less pressure, and a decreased importance of senior courses. The lack of interaction and friendships of senior students isn't as closed as junior classes and the senior students have higher independence. A university department may change their curriculum to help senior students maintain close friendships.

2. The formation and effects of social cliques: This research depicts that living together during freshman year can be the most decisive factor, followed by club participation and

gender identification in shaping a students' social life for the next 3 years. In comparison with the entire class, students of a subgroup have more consistent academic performances and higher attendance rates. This confirms the positive peer influence exerted by the subgroup.

3. The influence of the position in social networks: Student statuses are not equal in social networks. In this research, some particular students occupied the central position or hubs of a network such that the class forms a scale-free network. One of the key features of a scale-free network is that 20% of the nodes own 80% of the links. But there also are some peripheral or isolated students in the networks. Both the isolated students and the popular students need more work from student counseling to strengthen the resilience of network structure.

4. The discrepancy between friendship and learning networks: Learning networks, in contrast with the social networks, tend to be more fragmentary. The main causes may be fourfold: (1) students spend less time studying, (2) many students prefer to study alone, (3) limitations of the numbers of study partners, (4) the department does not provide courses that encourage group learning. We can conclude that students spend more time in social interaction than learning but the curriculum is also a major driving force in encouraging or discouraging students to learn.

5. The manifestation of student attributes in the social networks: Sex and geographical factor are two major causes for building close relationship because those minorities with similar backgrounds are easy to form groups. The university should endeavor to these differences among subgroups or cliques and to encourage student interactions because being open and diverse will benefit students and the university.

This research is a pilot study, which applies network theorems to analyze student social networks, and the result can be used to devise student counseling and to improve the quality of teaching.

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References

[1] Hsu, H. S. (2008). Advance or backward in social relationship – Conflicts and dilemma of social life. In C. C. Huang (Eds.), *Are you happy? Mental health of college students* (pp. 168). Taipei: Psychological publishing Co., Ltd.

[2] Ku, Y. N. (2008). Shuttle within people freely – The meaning and contents of interpersonal relationship. In C. C. Huang (Eds.), *Are you happy? Mental health of college students* (pp. 110), Taipei: Psychological publishing Co., Ltd.

[3] Huang, Y.C. & Lin, S. H. (2011). The Development of Academic Burnout Scale for College Students, Taipei, *Journal of Education and Psychology*, 34(4), 73-95.

[4] Karatizias, A., Power, K. G., Flemming, J., Lennan, F., & Swanson, V. (2002). The role of demographics, personality variables, and school stress on predicting school satisfaction/dissatisfaction: Review of the literature and research findings. *Educational Psychology*, 22(1):33-50.

[5] Yeh, S. K. (2009). Between wants and needs – About the adaptation and development of freshmen, In S. M. Chang, & S. M. Pan (Eds), *Learning processes and performances of Taiwan's college students* (pp.141-197). Taipei: Center for Educational Research and Evaluation, NTNU press.

[6] Huang, Y.C. Lin, S. H. & Liu, X. H. (2007). Sources of stress and coping strategies adopted by technology and junior college students. *Journal of Education and Psychology*, 30(2), 147-174.]

[7] Watts, D. J. (2003). *Six Degree: The Science of a Connected Age*. New York: Princeton University Press.

[8] Watts, D. J., & Strogatz, S. H. (1998). Collective dynamics of small-world networks. *Nature*, 393(6684), 440-442.

[9] Gartner, M. T., & Newman, M. E. J. (2004). Diffusion-based Method for Producing Density Equalizing Maps. *Proceeding of National Academy of Science of USA*, 101, 7499-7504.

[10] Sen, P., Dasgupta, S., Chatterjee, A., Sreeram, P. A., Mukherjee, G., & Manna, S. S. (2003). Small-World Properties of the Indian Railway Network. *Physical Review E*, 67, 036106.

[11] Buldyrev, S. V., Parshani, R., Paul, G., H., Stanley, E., & Havlin, S. (2010). Catastrophic cascade of failures in interdependent networks. *Nature*, 464, 1025-1028.

[12] Krempel, L. & Plümper, T. (2002). Exploring the Dynamics of International Trade by Combining the Comparative Advantages of Multivariate Statistics and Network Visualizations. *Journal of Social Structure*, 4(1), 1-22.

[13] Barabási, A.-L., & Bonabeau, E. (2003). Scale-Free Networks. *Scientific American*, 288, 50-59.

[14] Cohen, R., Erez, K., & Havlin, S. (2000). Resilience of the Internet to random breakdowns. *Physical Review Letters*, 85(21), 4626-4628.

[15] Andre, M., Ijaz, K, Tillinghast, J. D., Krebs, V. E., Diem, L. A., Metchock, B., Crisp, T., & McElroy, P. D. (2006).Transmission Network Analysis to Complement Routine Tuberculosis Contact Investigations. *American Journal of Public Health*, 96(11), 1-8.

[16] Klerks, P. (2001). The Network Paradigm Applied to Criminal Organisations: Theoretical nitpicking or a relevant doctrine for investigators? *Recent developments in the Netherlands, Connections*, 24(3), 53-65.

[17] Schwartz, D. M., & Rouselle, T. (2009). Using social network analysis to target criminal networks. *Trends of Organized Crimes*, 12, 188–207.

[18] Krebs, V. E. (2002). Mapping Networks of Terrorist Cells. *Connections*, 24(3), 43-52.

[19] Adamic, L. A. & Glance, N. (2005). *The Political Blogosphere and the 2004 U.S. Election: Divided They Blog*, Proceedings of the 3rd international workshop on link discovery (pp. 36–43). New York: ACM. DOI: 10.1145/1134271.1134277.

[20] Chen, L. L., Blumm, N., Christaksis, N. B., Barabási, A-L., & Deisboeck, T. S. (2009). Cancer Metastasis Networks and Prediction of Progress Patter. *British Journal of Cancer*, 101, 749-758.

[21] Moody, J. (2001). Race, School Integration, and Friendship Segregation in America. *American Journal of Sociology*, 107(3), 679–716.

[22] Heck, R. H., Price, C. L., & Thomas, S. L. (2004). Tracks as Emergent Structures: A Network Analysis of Student Differentiation in a High School. *American Journal of Education*, 110(4), 321-353.

[24] Bothner, M. S., Smith, E. B., & White, H. C. (2010). A Model of Robust Positions in Social Networks. *American Journal of Sociology*, 116(3), 943-92.

[23] Quiroz, P. A., Gonzalez, N. F., & Frank, K. A. (1996). Carving a Niche in the High School Social Structure: Formal and Informal Constraints on Participation in the Extracurriculum. *Research in Sociology of Education*, 11, 93–120.

[25] Roxå, T., Mårtensson, K., & Alveteg, M. (2011). Understanding and influencing teaching and learning cultures at university: a network approach. *Higher Education*, 62, 99–111.

[26] Simon, H. A. (1955). On a class of skew2 distribution functions. *Biometrika*, 42, 425-440.

[27] Newman, M. E. J. (2010). *Network: An Introduction.* New York: Oxford University Press Inc.