Network Analysis of Cooperative Learning

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Abstract

We contrast two cooperative asynchronous learning groups - one structured, the other non-structured. The outcome was measured by content analysis. The cohesion and role structures were analyzed by Social Network Analysis. The structured group constructed knowledge at high levels of critical thinking, developed a mesh of interconnected cliques, and students undertook bridging and leading roles. The non-structured group constructed knowledge at low level of cognitive activities, few cliques were constructed, and most of the students undertook the simple role of teacher followers. This provides empirical support for the idea that structuring cooperative learning groups develop cohesion and role structures that are associated with knowledge construction at high levels of critical thinking.

Introduction

Johnson (Johnson, 1999) suggested that the structural design of a cooperative learning group determine the intra social relations, which in turn determine the outcome of the cooperation. The structure of the social relations can be analyzed using Social Network Analysis (Wasserman & Faust, 1999), and the outcome is evaluated by Content Analysis of the transcript of the communication (Gunawardena, Lowe & Anderson, 1997).

Social Network Analysis (SNA) provides insight to the behavior of groups. Prominence characteristics of distance learner networks were identified (Haythornthwaite,1998). Evolution of cohesion was studied (Reffay & Chanier,2002), and Centrality across activities (Cho, Stefanone & Gay, 2001).

We use constructivist paradigm (Jonassen, 1994). Rafaeli argued that constructive communication is determined by its responsiveness (Rafaeli, 1988). Accordingly, we analyze the network structures of the responsiveness

relation between learners in asynchronous groups. Burt (Burt, 1991), noted that cohesion structure is a driving force for "sharing beliefs and behavior" i.e. for knowledge construction. In addition, certain *roles* are required - to bridge over periods of silence or to silent participants (Aviv, 2000). We hypothesize that the cohesion forces and bridging roles are factors in determining the quality of the Knowledge Construction Process. To test this hypothesis we analyze two different asynchronous online discussion groups (called *forums*). We test the following assertion: *marked difference in designs of forums is associated with marked distinction in the cohesion and role structures of the forums, which is associated with marked distinction in the critical thinking levels of the Knowledge Construction Processes of the forums.*

The Test-bed

We analyze transcripts of two forums that were parts of the Open University of Israel course 10523 *Business Ethics*. One forum (18 participants) ran during 2000 fall semester. The other forum (19 participants) ran during 2002 spring semester. The designs of the forums were different. The 2000 fall forum was more structured then the 2002 spring one. Hence we label the forums as the *structured forum* and the *non-structured* forum respectively. The data is available at http://telem.openu.ac.il/courses

The forums were three-months long. The structured forum was a formal debate. Participants committed to active participation, with an associated reward in place. Students were an "advisory committee" that has to advise a company how to handle the Business/Ethical problem of cellular phone emissions. The debate scheduled as a five 3-week steps, enforcing a process of moral decision making (Geva, 2000): First step - identify facts, debate solutions & propose a synthesis. Next three steps: Test the synthesized solution against prescribed sets of principles. Last step: provide a summary. See Geva (Geva, 2000).

The non-structured forum was open to all students in the course. Students and the tutor were to raise a variety of issues related to the course topics. No structure or schedule or reward mechanisms were designed.

The SNA was done by *Cyram NetMiner* - a software tool for exploratory network data analysis and visualization [Netminer, 2002]. We developed a conversion program, *Opus2Ntf.exe* -a Visual Basic .Net utility that scans the SQL database of the transcript of a given forum, constructing the Response Matrix of the forum: The (i, j) entry is the number of messages sent by member i responding to messages sent by j. The content of the Response Matrices was the input to the clique and role analysis by *NetMiner.*

Content Analysis of the Knowledge Construction

The structured forum had 248 messages. The non-structured forum had 70. In performing the content analysis we classified each message to one or more of the five levels of the Interaction Analysis Model (Gunawardena, Lowe

& Anderson, 1997). Coding was by three researchers until agreement was reached. Table 1 summarizes the results.

Table 1: Classification of messages in the two Forums

Level	Meaning	Str. Forum	Non-Str. Forum
I	Sharing/Comparing information	38	70
II	Discovery of dissonance/inconsistency	34	
III	Synthesis via Negotiation of meaning	28	
IV	Testing against prescribed principles	143	
V	Summary/Application of Knowledge	5	

The structured forum was designed as a series of time bounded steps, specifically directing the students into increasing levels of critical thinking, up to and including level IV of the Interaction Analysis Model. This is what we see in the table. Each student in the non-structured forum used the forum according to its own needs. Many of the transactions were simple Q&A, triggered by students' assignments in the other parts of the course. None of these questions developed into critical thinking beyond the bottom level, I.

Cohesion Analysis

Burt (Burt, 1991) noted that some of the socializing bonds developed in a group are encoded as strongly connected cliques identified by cohesion analysis methods. A *clique* is a maximal connected sub-group. The degree to which strong links are within the clique rather then outside of the clique is measured by the *Cohesion Index*. For details see (Bock & Husain, 1950). Table 3 presents the result of performing clique analysis on the two forums.

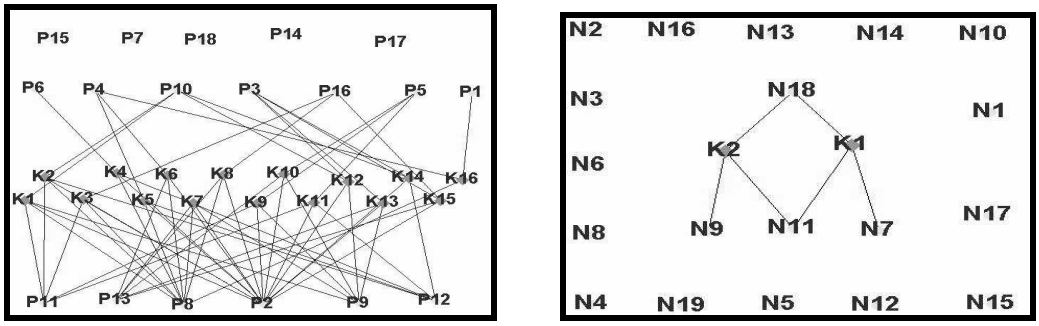
Table 2: Clique Analysis Reports

Non-structured Forum		**Structured Forum**	
# cliques: 2		# Cliques: 16	
Cliques	**Cohesion index**	**Cliques**	**Cohesion Index**
K1: **N18**, N11, N7	3.826	K1: P2, P8, P11, P10, P9	3.333
		K2: P2, P8, P11, P10, P12	2.786
		K3: P2, P8, P11, P16	2.147
		K4: P2, P8, P6, P12	2.439
		K5: P2, P8, P4, P12	3.073
		K6: P2, P8, P4, P13	3.033
		K7: P2, P8, P13, P9	1.974
		K8: P2, P8, P13, P16	1.810
K2: **N18**, N11, N9	2.000	K9: P2, P5, P9, P11	2.388
		K10: P2, P5, P9, P11	1.420
		K11: P2, P5, P12, P11	1.970
		K12: P2, P3, yafi, P10	3.200
		K13: P2, P3, P9, P13	2.227
		K14: P2, P3, P12, P10	3.792
		K15: P2, P3, P16, P13	2.217
		K16: **P1**, P4, P8	1.607

Note that there are two cliques in the non-structured forum, 16 in the structured forum. Next, students in the structured forum form relatively large cliques - at least four students each (except K16); that is, they maintained response relations with several others. Moreover, the tutor (**P1**) participated in one clique only (K16). The cliques in the non-structured form include only two students, and the tutor (**N18)**. Difference in inter-clique connectivity (actors belonging to more then one clique) is striking: Many students of the structured forum belong to more then one clique. This bridges wealth of information flows to all members. Bridging is visualized by the clique bipartite graph (Figure 1). These graphs include clique nodes (**Ki**) and actor nodes. Membership is represented by links. Note the single membership of the tutor (**P1)** in the structured forum**.**

Figure 1. Clique Bipartite Graph

Left: structured forum **Right: non-structured forum**

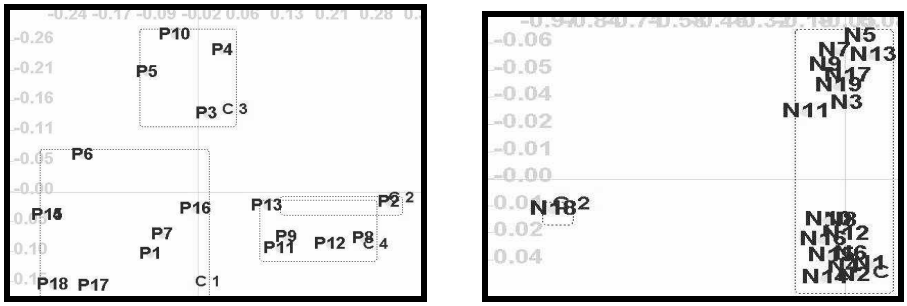


Role Analysis

Role Analysis of network group actors that implement certain social roles in the network into *role groups*. Individuals in one role group are equivalent in the sense that as far as the social roles these individual implement, they can replace each other. The analysis is described in Humel & Sodeur (1987) and in Burt (1991). The role groups of the two forums are presented in Figure 2 using Classical Multidimensional Scaling.

Figure 2. Role groups:

Left: Structured Forum **Right: non-structured forum**

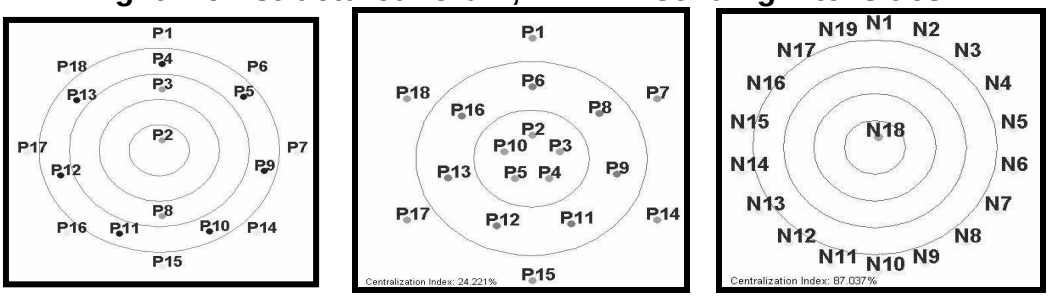


In the structured forum (Figure 2, Left) role group **C2** consists of a single actor - **P2** – the actor that bridges 15 cliques (see Figure 1). Similarly, role group **C4** consists of all the other strong bridges – those that connect to at

least four cliques. Eight actors are included in role group **C1**, and four actors in **C3**. The roles of these two clusters are revealed from the Network Centrality Maps presented in Figure 3. In Figure 3 relative intensity of *receiving and sending* responses are presented: the more active actors are closer to the center. Bonacich eigenvector algorithm (Bonacich, 1972; Freeman, 1979) was used to calculate the combined sending and receiving intensities in the structured forum (Figure 3, left box). One can see that members of role group **C1** are all on the fringe – they took the role of lurkers. Once again **P2** is the most active member of the forum. The relative intensity of *receiving* responses in the structured forum is presented in the middle box. The central *attractors* are role group **C3** (and ***P2***).

Figure 3: Centrality Maps

Left: Structured forum, combined send/receive intensities
Middle: Structured forum, receiving intensities
Right: non-structured forum, sending intensities



Consider now the role groups of the non-structured forum (Figure 2, right). Group **C3** consists of the tutor (**N18**). The special role of the tutor is seen in Figure 3, right box – the centrality map of the *sending responses*. In this forum the tutor responded to all other participants. The forum was Q & A.

Discussion

We provided empirical support for the assertion that the structured design lead to high degree of cohesion. Furthermore, some of the students implicitly undertook bridging roles, without which the operation might have lead to split groups or gaps in the debate. Why did they do it? There is no guarantee that this will happen in every (structured) cooperative group. This calls for further research concerning the attributes and motives of the students. Other lines of research might be:

Network Dynamics: inquiring into the time development of networks structures. When do clique develop? Are they stable?

Information Overload: The dynamics of large groups lead to boundary effects (Jones, Ravid & Rafaeli, 2001) How these are manifested in learning groups?

Network: Efficiency: Increasing network density might lead to redundant connectivity (Burt 1992, 2002); efficient network has "holes" around actors. Does a well designed cooperative network develop into a more or less efficient network?

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