Network Structure Analysis Approach to Knowledge Building: A Macroscopic View of Group Dynamics in Discourse

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Abstract: In the classroom, the knowledge building is represented as emergent collaborative learning on ill-structured tasks. It is difficult to capture group dynamics of knowledge advancement by using our currently available methodological approaches. The study is aimed at developing the network structure analysis of discourse for capturing such a dynamics. We analyzed discourse from two groups of secondary school students that were engaged in different modes of collaborative learning, knowledge-sharing and knowledge-creation. The network structure analysis showed crucial differences in group dynamics between the groups: (1) students in the knowledge-creation group were more cognitively-oriented, (2) knowledge integration was found stable in the knowledge-creation group over the learning period, and (3) contribution to knowledge advancement was symmetric in the knowledge-creation group. Based on the results, authors discuss a possible integrative analysis framework of microscopic and macroscopic approaches to the assessment of knowledge building activities.

Research Backgrounds and Purposes

Knowledge building appears as emergent collaborative learning with ill-structured tasks in the classroom. Because of its unique natures, knowledge building is difficult to capture by analysis approaches that we have used. In this section, we attempt to identify the unique natures of knowledge building by comparing it with ordinary collaborative learning, and articulate how our current approaches to discourse analysis might fail to capture the natures.

Collaborative learning conducted successfully in the classroom is well-structured. Fixed size of small groups are involved in some challenging tasks across specific period of time. In some cases like scripted cooperation or reciprocal teaching, students' roles are specified for the purpose of creating ideal form of collaboration. Knowledge building, on the other hand, is quite opposite to this stream. Students are encouraged to collaborate with one another in a flexible manner even though they are allocated into groups. Time schedule should not be fixed because of its emergent nature. We do not expect students to see the end of their learning. Students are naturally involved in various cognitive roles in their collaboration.

How do we approach to such emergent natures of knowledge building for the assessment of learners' knowledge advancement? So far, researchers have applied three methodological approaches. One approach to capture the natures is to establish the rubrics of content knowledge that researchers expect learners to acquire after their learning. They can identify whether learners' knowledge advances or not based on their established rubrics. Second, researchers approach to analyzing the process of learning by breaking it into small units to categorize into different cognitive actions. With this approach, they can identify patterns or models of cognitive processes that students engage in. Third, fine-grained discourse analysis as a case study also helps them describe what is happening in students' collaborative learning. The combination of the discourse analysis and narratives is a popular methodology to analyze the classroom environment.

Although the three approaches are appropriate to discuss well-structured collaborative learning, any approach is not an appropriate tool to capture collective knowledge advancement. Regarding the content of knowledge, we are not only concerned with deep comprehension of domain-specific knowledge but also epistemic agency by learners to advance their collective knowledge. Since the epistemic agency is process-oriented, static evaluation of knowledge does not catch its dynamics. Categorization of cognitive processes learners engage in might capture the epistemic agency, but it is so content-free that we cannot describe what knowledge learners actually develop. Consequently, fine-grained discourse analysis with narratives would be the last option. Although a microscopic view of discourse analysis provides us with details of how learners develop their collective knowledge within a period of time, we also need to describe its macroscopic view so that we can verify why the detected microscopic discourse should be important to argue and how the detected pieces of discourses are placed in the macro structure of collaboration. In this paper, we propose the network structure analysis of discourse as a macroscopic view of analysis on knowledge building. First, we briefly review the network science studies, and how the approach can be applied to discourse on Knowledge Forum®. Secondary, we demonstrate currently developing methodology of analyzing discourse from the macroscopic view, and discuss how the methodology can be integrated with the microscopic view of discourse analysis.

The Network Science Approach as a Macroscopic Discourse Analysis

The *complexity* is a key concept in the 21st century science (Watts, 2007). Agents having a variety of resources are linked to one another in multi-layer communication tools. The network structure created through such communication generates new insights and creates new knowledge (Davis, & Sumara, 2006; Scardamalia, & Bereiter, 2005). The *complex network theory* (e.g., Strogatz, 2001) is an analytic approach to describing a variety of network structures developed based on statistical physics, and discovered several important features (i.e., the Small World, the Scale-Free, etc.). Oshima et al. (2007) argued that the network science approach was useful for evaluating collective knowledge advancement in CSCL, and demonstrated how the complexity system based on discourse on the genetically modified foods by 5th grade students was different from that by experts. Zhang et al. (2009) used the social network analysis to visualize and compare 4th grade classroom collaboration on Knowledge Forum® across three years, and concluded that knowledge advancement was facilitated when the participation structure was more distributed. These studies are focused on the issue of how to appropriately visualize a macro structure of collaboration, but not concerned with its relation to microscopic discourse analysis. In this study, we consider how to make the macroscopic discourse analysis informative for the microscopic discourse analysis. Particularly, we attempt to focus our attention to learners' individual differences in contributions to discourse in collaborative learning.

A Macroscopic Analysis of Discourse by 10th- and 11th-Grade Students on Knowledge Forum®

Target Group and Data

In this study, we used the same data analyzed by Jan van Aalst (2009). Here, we describe target groups and data by referring to van Aalst (2009).

The participants were two classes of secondary school students, from a 10th grade course on career preparation and inquiry (n=21) and a 11th grade course focusing on computers and their impact on "global society" (n=19). The courses were taught concurrently by the same teacher at an inner city school in Western Canada. Approximately 40% of the students had some experience with Knowledge Forum® in previous grades, such as in discussing "problems of the week" in mathematics. The teacher had 10 years of experience teaching secondary school mathematics.

The topics that students challenged were "the outbreaks of Severe Acute Respiratory Syndrome (SARS)" and "Avian Flu in 2003 and 2004." Students could build on their knowledge of science to study what was known about these phenomena, critique media attention, examine the economic impact, or form a position on how governments should have responded to the outbreaks. The 10th grade course provided a promising context for integrating a focus on such questions into the curriculum, as one of its main goals was learning how to conduct research. The 11th grade course also provided a good opportunity to engage in knowledge creation, as one of its main goals was for students to learn how information and communication technology could be utilized for learning in global societies. The second main topic on the 11th grade course syllabus was "computer viruses," which was added to SARS and Avian Flu as a third main topic for inquiry with the aim of having the students examine the nature of viruses in both biological and non-biological systems and identify patterns across them.

The two classes shared a Knowledge Forum® database and worked on the same topics. To limit the number of notes they would encounter, the students were divided into four groups. Each group had students from both classes, with an equal number of students from each class; the students could choose their own groups but the teacher made some minor changes. Each group had its own views on Knowledge Forum and the groups were not expected to interact with each other during the inquiry. In the week before the project commenced, all students responded to an icebreaker topic. The researcher then introduced both classes to knowledge-creation principles, and students were reminded of these by means of posters in their classrooms.

Both classes had daily access to a computer lab (70-minute periods), but students had a number of other assignments to complete. During typical periods, the teacher would spend 10 to 20 min interacting with the whole class, and the students would then work on one of their assignments. Most of the students worked on Knowledge Forum® during class a few times per week, and after school hours. The teacher discussed the students' work in Knowledge Forum® with them from time to time, but he only read 23% of their notes and posted 7 of his own.

Based on the analysis, van Aalst (2009) identified natures of the four groups. The profile of Group A was most consistent with knowledge creation: It included nine predictions of that mode, of which only one was degenerate. It also included two predictions of knowledge sharing. The overall fit of the predictions to the discourse mode was best for this group. The profile of Group D was almost the reverse: it had nine predictions of knowledge sharing (seven non-degenerate) but included more predictions of the other modes than the Group A profile. The profiles of Groups B and C were more difficult to interpret because they included nearly equal numbers of predictions of all three of the discourse types. This could be caused by a variety of factors including the existence of smaller units of social organization that approach the discourse differently and contextual dependencies that cause the discourse on one problem to be qualitatively different from that on another. In this study, we attempted to characterize collective knowledge advancement by Group A and D, and differences in natures of the two groups.

The Network Structure Analysis of Discourse on Knowledge Forum®: Individual and Group Differences in Contributions to Discourse

Two researchers (Jun Oshima and his graduate student) detected 409 noun words as indices of student understanding (the agreement was over .80). Based on their evaluation, we created a *bipartite* representation of student discourse (words X notes) to visualize network structures of notes and words by each group. In addition, the same researchers evaluated each note as either *cognitively meaningful* that meant that the note was important for students to advance their understanding in discourse or not (the agreement was over .95). We utilized the *betweeness centrality coefficient* (BC) as a measure for student contribution to discourse. The BC ranges from 0 to 1 meaning that high coefficient manifests that a note mediates other notes in a cognitively meaningful way based on the detected noun words.

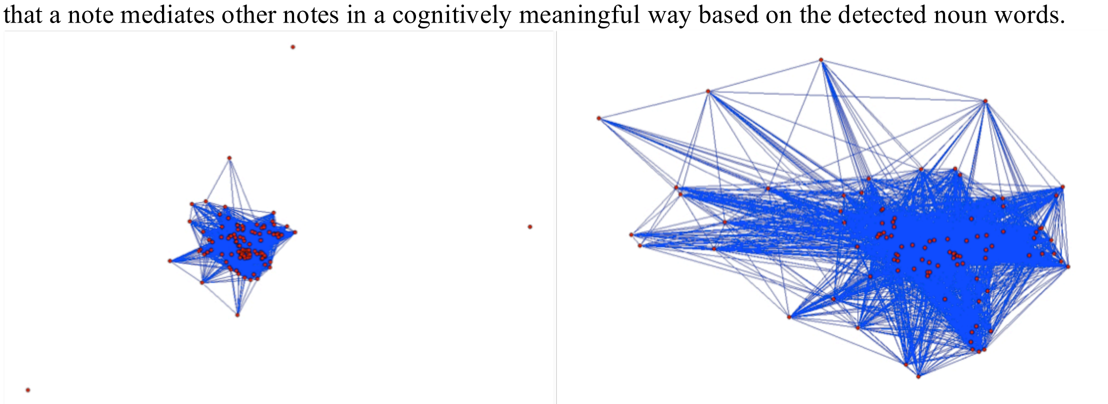

Figure 1. Network Structures of Notes by Group A (left) and D (right).

First, we attempted to describe group differences in natures of collaboration between Group A and D by analyzing the network structures of notes. Two *t*-tests of mean BCs between cognitively meaningful notes and non-meaningful notes within groups manifested that a mean BC of cognitively-meaningful notes was significantly higher than that of non-meaningful notes in Group A, $t(130) = 3.032$, $p < 0.01$. There was no significant difference in Group D. Further, we compared mean BCs across three different phases between groups. 2 (Groups) X 3 (Phases) ANOVA on mean BCs showed the interaction effect, $F(3,198) = 9.7098$, $p < 0.01$, manifesting that there were no significant differences in mean BCs across phases in Group A whereas BCs significantly decreased across phases in Group D (Figure 2).

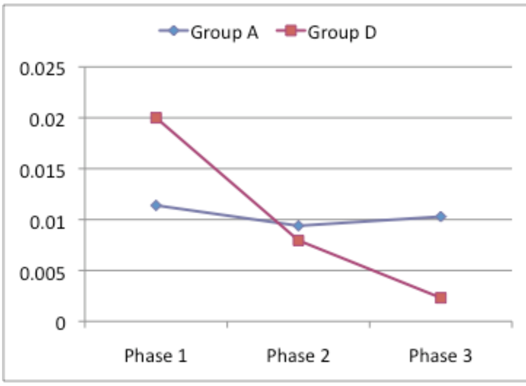

Figure 2. Changes in Mean BCs of Cognitively Meaningful Notes Across Phases.

Second, we assessed individual student's contribution to collective knowledge advancement by analyzing the network structure of words (Figure 3). For calculating each individual's contribution to the knowledge advancement, we developed a mathematical procedure called stepwise analysis (Oshima et al., 2007). In the stepwise analysis of network structure, each individual's contribution was calculated as a mean of *absolute* values of change in BCs of words that have great contributions to the network structure when notes created by a target student was completely omitted from the data set. In other words, we compared BCs of words representing the network structure between with a target student's notes as data and without it.

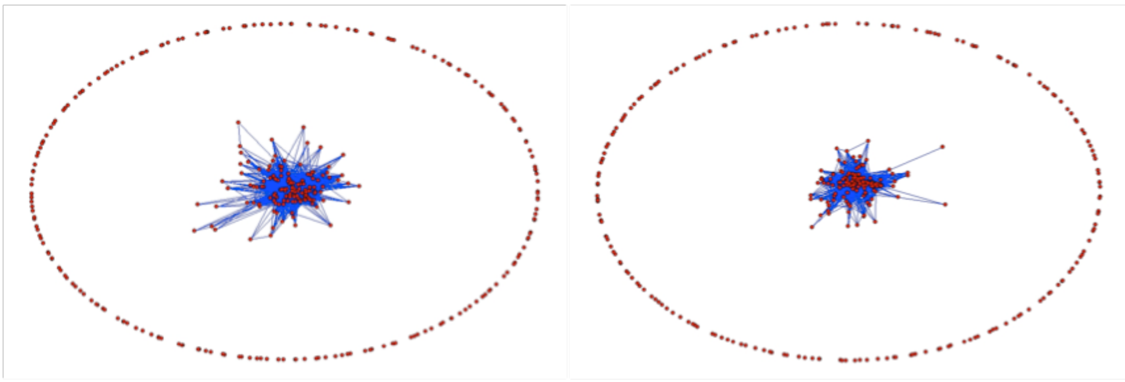

Figure 3. The Network Structures of Words by Group A (left) and Group D (right).

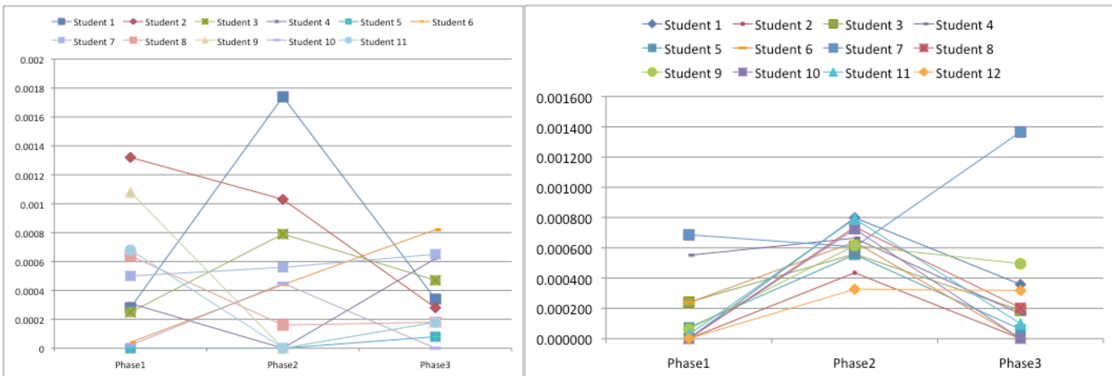

Figure 4. Students' Contributions to the Network Structures of Words
Across Phases in Group A (left) and Group D (right).

11 (Students) X 3 (Phases) ANOVA on mean absolute values of changes in BCs manifested that different students contributed much in different phases in Group A. On the other hand, 12 (Students) X 3 (Phases) ANOVA manifested that students had quite similar contribution patterns excluding a specific student (#7).

Discussion

This study was aimed at developing a macroscopic discourse analysis methodology by using the network structure analysis. For this purpose, we re-analyzed students' discourse data that had been already identified as knowledge-creation type (Group A) and knowledge-sharing type (Group D), and speculated group and individual differences in students' contributions to collective knowledge advancement. The network structure analysis manifested crucial differences between knowledge-creation and knowledge-sharing groups as follows: First, the network structure analysis suggested that students in the knowledge-creation group were more cognitively oriented than was the knowledge-sharing group. Although the knowledge-creation group produced a few non-meaningful notes, no one usually followed up. They were found to be more focused on problems they inquired. Secondary, the knowledge-creation group was engaged in their collective knowledge advancement in a quite stable manner across three phases. The result suggests their continuous involvement of collective knowledge advancement. Finally, contributions by students in the knowledge-creation group were divergent across phases. Different individuals contributed in different ways at different phases. This result suggests that the organization of inquiries might be distributed across individuals and its structure made them contribute to their knowledge advancement in unique ways.

Thus, the network structure analysis has possible advantages to describe group dynamics of collective knowledge advancement. On the basis of this case study, we plan to further analyze various data sets to establish generalizable procedures and the integrative framework of micro- and macro-scopic discourse analysis.

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