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

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Methodological Problems with Capturing kb

- Collective knowledge advancement appears as emergent collaborative learning on ill-structured problems
  - Dynamic and emergent collaboration among learners
    - Activity structures such as groups are not fixed
    - Learning period is long
  - Problem solving is progressive, i.e., seeking for new knowledge
    - Learning goals are not pre-determined, but changed over time

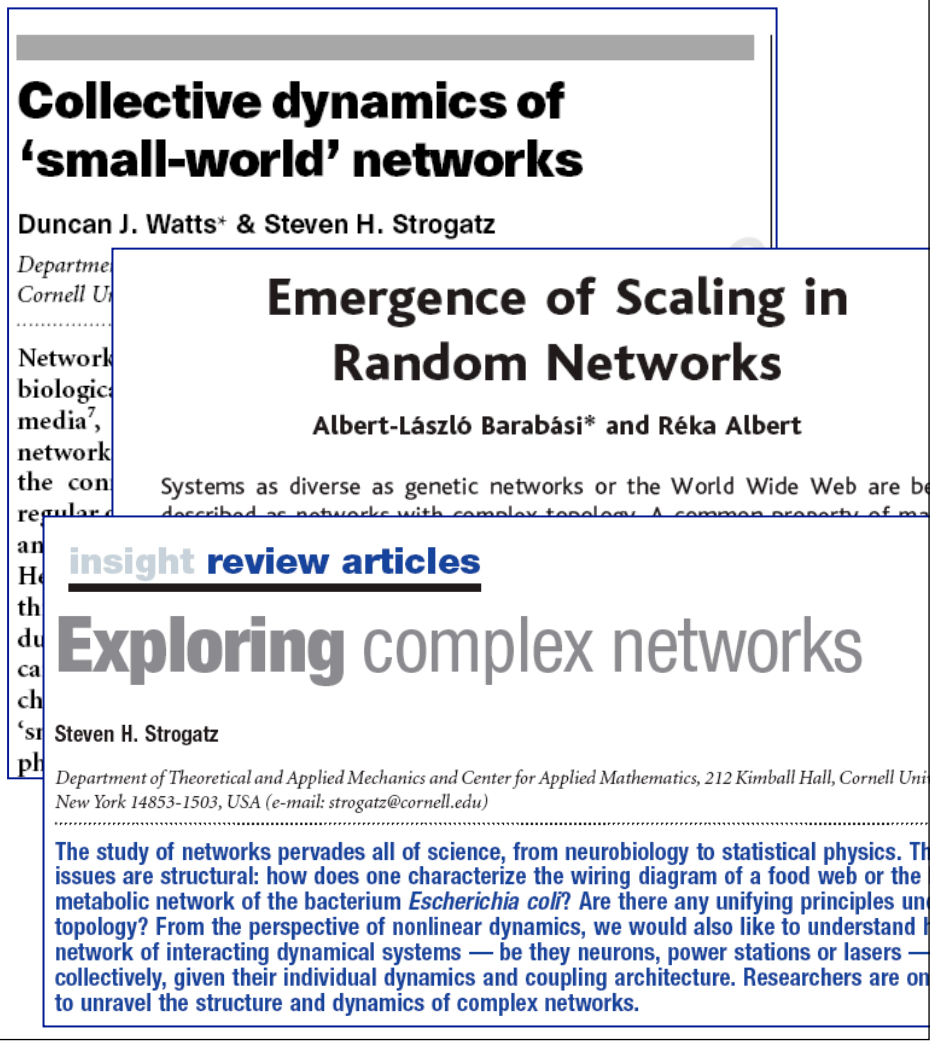
A New Approach to Collective Knowledge Advancement

- Ordinary methodological approach for knowledge building discourse
  - in-depth discourse analysis to demonstrate or speculate how knowledge building happens
  - narratives for describing a grand story behind pivotal points of knowledge building

- We would need a macroscopic analysis of kb discourse
  - the analysis should be objective
  - it should capture at least some aspects of kb, i.e., emergence of ideas or collective knowledge advancement

The Complex Network Science as a Way to Capture Collective Knowledge Advancement

- It explores general laws hidden in the complex network systems (Strogatz, 2001)
- The simulation and analysis of network structures have found
  - Small-world characteristics as the mechanism explaining the *six-degrees of separation* (Watts, & Strogatz, 1999)
  - Scale-free characteristics reflecting *long-tail distributions* (Barabasí, & Albert, 1999)



Collective dynamics of 'small-world' networks

Duncan J. Watts* & Steven H. Strogatz

Emergence of Scaling in Random Networks

Albert-László Barabási* and Réka Albert

Systems as diverse as genetic networks or the World Wide Web are be

insight review articles

Exploring complex networks

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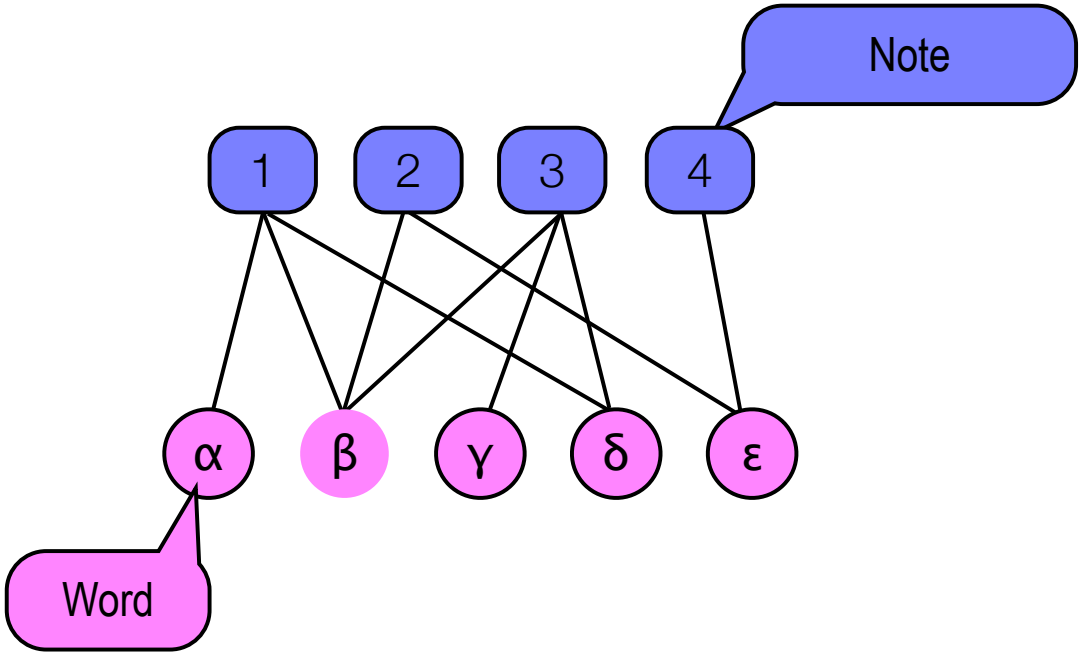
The study of networks pervades all of science, from neurobiology to statistical physics. Th
issues are structural: how does one characterize the wiring diagram of a food web or the
metabolic network of the bacterium *Escherichia coli*? Are there any unifying principles un
topology? From the perspective of nonlinear dynamics, we would also like to understand h
network of interacting dynamical systems — be they neurons, power stations or lasers —
collectively, given their individual dynamics and coupling architecture. Researchers are on
to unravel the structure and dynamics of complex networks.

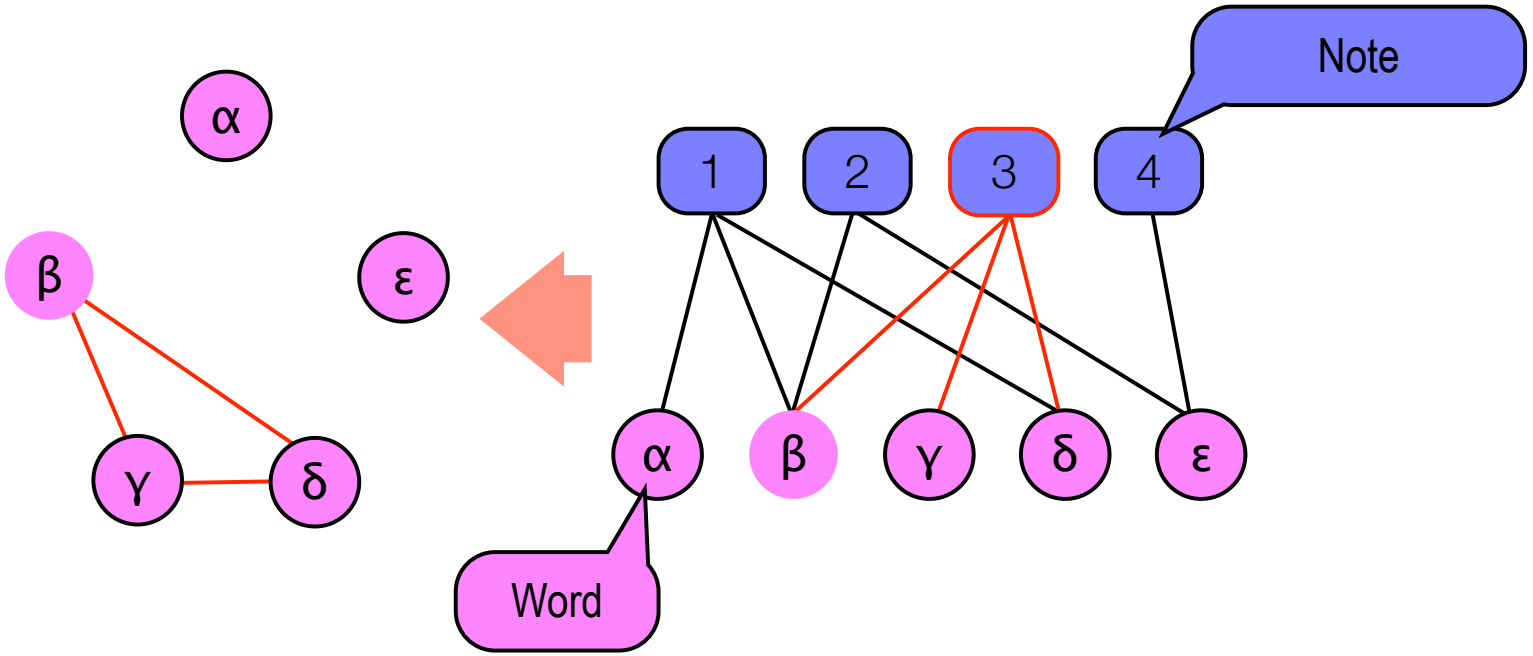
Network Structure Analysis

- Bipartite Graph of notes and words



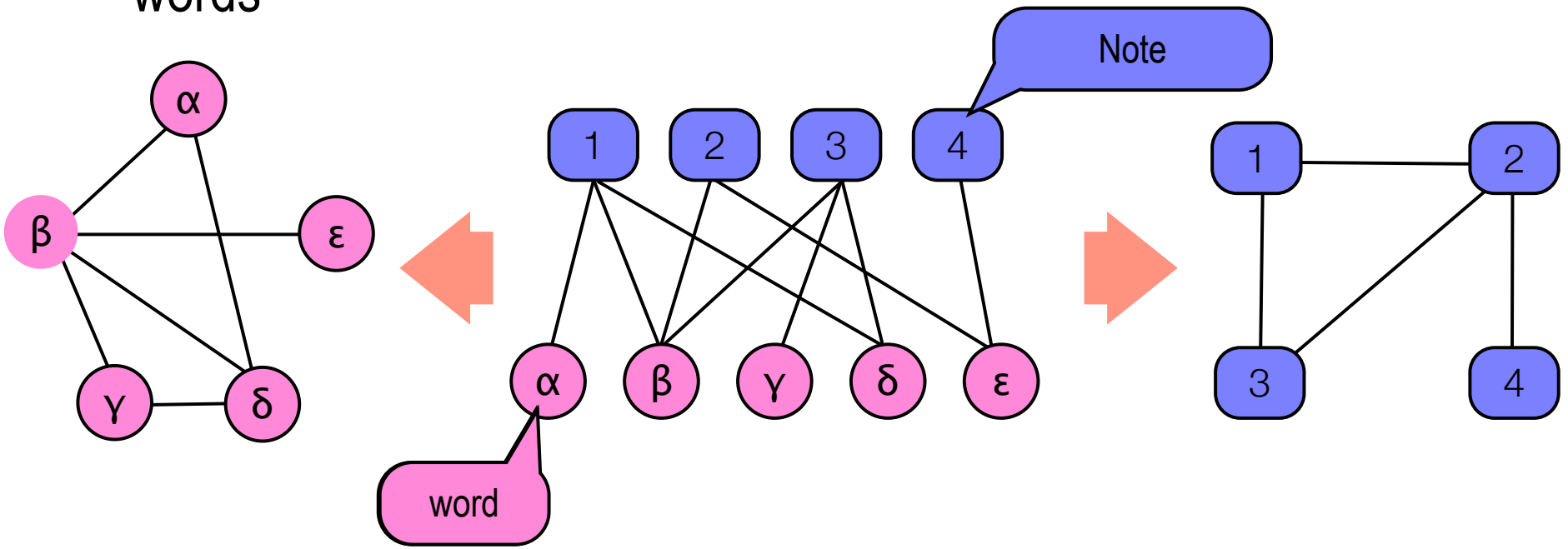
Network Structure Analysis

- Bipartite Graph of notes and words
  - A network structure of words based on the co-occurrence within same notes



Network Structure Analysis

- Bipartite Graph of replies and words
  - A network structure of words based on the co-occurrence within same replies
  - Another network structure of replies based on the co-occurrence of words



Exploratory Study

- Purpose of the study
  - Exploration of how to evaluate collective knowledge advancement by applying the complex network science to KF discourse data

- Study design
  - Data sets: Discourse by knowledge-creation and knowledge-sharing groups of 10th- and 11th-grade students in van Aalst (2009)
  - Research questions

    Is there any crucial differences in collective knowledge advancement between the groups?

Exploratory Study

- Aspects of collective knowledge advancement could be captured by the network structure analysis

I. *idea diversity*. With the network of conceptual and epistemological words, we can identify which words specific students used in their notes and calculate their contribution to the network structure.

II. *community knowledge, collective responsibility*. With the networks of notes (or conversation turn) and conceptual (epistemological words), we can evaluate how each student participate in discourse moment by moment.

Exploratory Study

- Aspects of collective knowledge advancement could be captured by the network structure analysis

III.*symmetric knowledge advancement*. With the network of conceptual and epistemological words, we can identify which words specific students used in their notes and calculate their contribution to the network structure.

IV.*embedded and transformative assessment*. With the networks of notes (or conversation turn) and conceptual (epistemological words), we can evaluate how each student participate in discourse moment by moment.

Network Analysis: Procedure

- Bipartite graphs (Words X Notes) were created in each group across different phases
  - 409 noun words (content-related + epistemic)
  - Activity phases
    - Phase 1 (2 weeks): Finding problems for their inquiries
    - Phase 2 (4 weeks): Pursuing their selected problems
    - Phase 3 (2 weeks): Summarizing their learning

An Indicator of the Network Structure

- Betweeness Centrality (BC)
  - Coefficient for every node ranging from 0 to 1
  - Index of how a specific node mediates other nodes
    - High BCs mean that notes (words) work as mediators for other notes (words)

$$C_v(u) = \sum_{s,t \neq u} \frac{\sigma_{st}(u)}{\sigma_{st}}$$

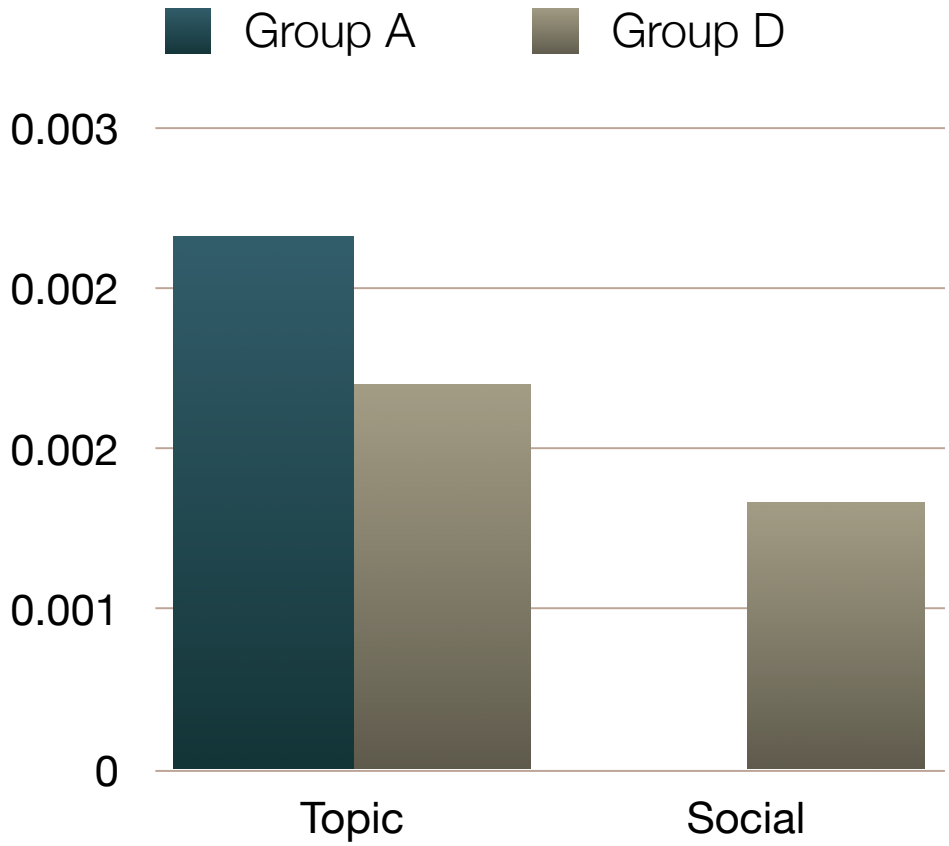
Analysis Plans

- Analysis of the Network Structure of Notes
  - Exploration of visualization of the network structures
  - Differences in BCs between topic-oriented and social communication notes
  - Differences in BCs among 3 phases (between groups)

- Analysis of the Network Structure of Words
  - Exploration of visualization of the network structures
  - Magnitudes of contributions by students across phases (between groups) ▶Stepwise analysis

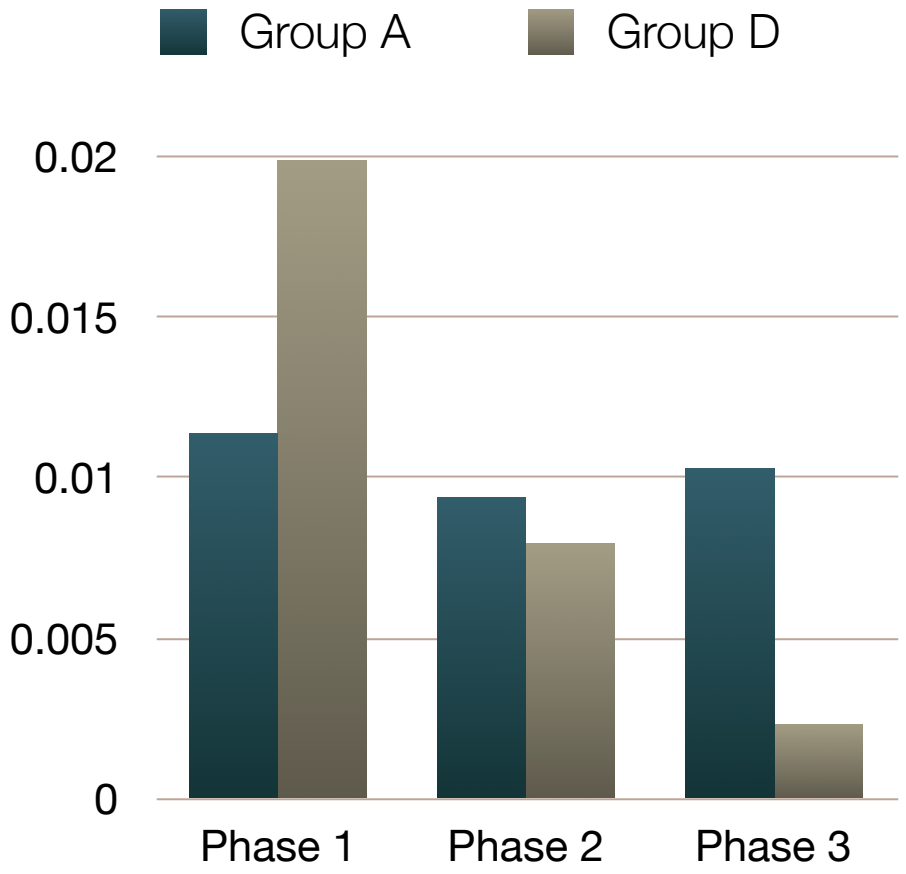
Results: Topic-related vs. Social communication

- Group A
  - BCs of topic-related notes were significantly higher than those of social communication notes, $t(130) = -3.032$, $p < 0.01$.
- Group D
  - There was no difference in BCs between topic-related and social communication notes.

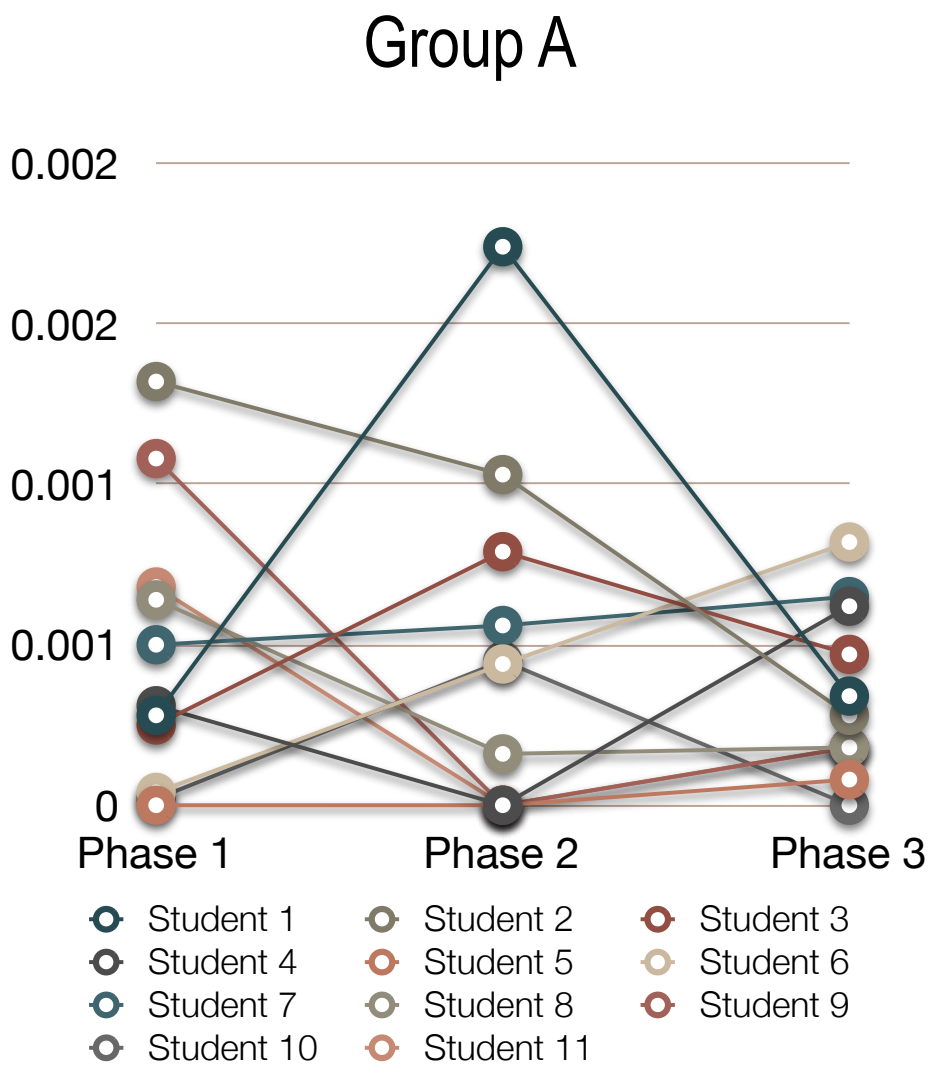


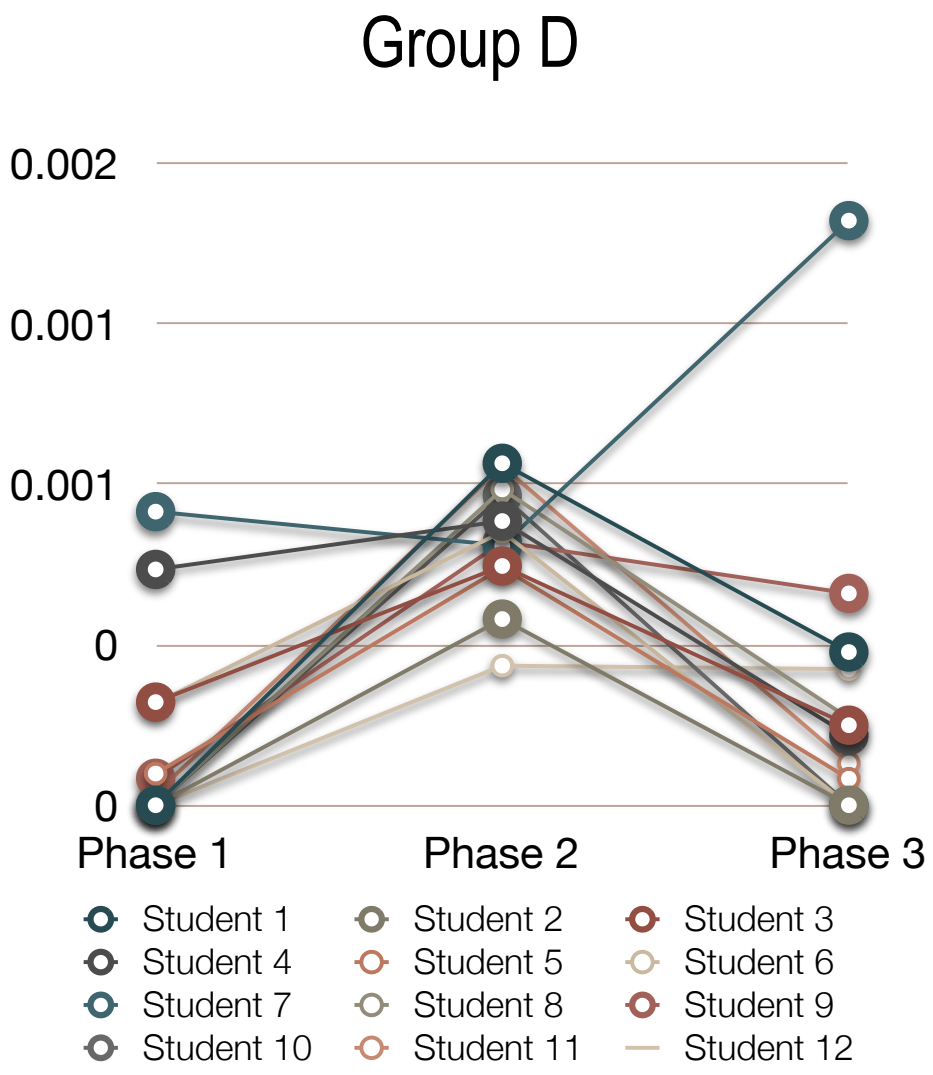
Results: BCs of topic-related notes across phases

- A Group X Phase ANOVA on BCs showed the interaction effect, $F(3,198) = 9.7098$, $p < 0.01$.
  - BCs of notes by Group A remained stable across phases whereas those by Group D decreased significantly.



Results: Students' contribution to the network structures of words





Characteristics of Group Dynamics Found by the Network Structure Analysis

- Group A: **Knowledge Creation Group**
  - Discourse was **more topic-oriented**
  - **Structuring conceptual words was stable** across phases
  - **Different students contributed** to network structure of conceptual words in different phases
- Group D: Knowledge Sharing Group
  - Discourse was **cognitively and socially-oriented**
  - Trend of **knowledge integration was decreased** across phases
  - Contribution by students were **mostly the same excluding one big contributor**

Further Studies

- Development of Knowledge Building Discourse Explorer (KBDeX) as **a platform application**
  - Any researchers and practitioners can explore their learners' discourse from the perspective of knowledge building as the complexity system
- Establishment of **grounded theory approach to knowledge building discourse**
  - The macroscopic analysis like KBDeX should function like the exploratory factor analysis > We need to establish how to interpret results