

Roles of Engagement: Networks in PER

Physics Department Colloquium - Rowan University

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Hurricane Sandy

What caused Hurricane Sandy?

- Global Warming
 - Increased oceanic temperatures
 - Disruption of climate patterns
 - Sea level rise
- But this is a system of causes, not a singular direct cause.



Figure: Jersey Shore Post Sandy

Learning

What causes learning?

■ Active Learning

- Curriculum
- Pedagogy
- Instructors
- Mindset



See where this is heading?



Figure: Active Learning at Drexel

Learning

What causes learning?

■ Active Learning

- Curriculum
- Pedagogy
- Instructors
- Mindset
- Context
- Blood sugar levels
- etc...

See where this is heading?



Figure: Active Learning at Drexel

Direct and Systemic Causation

Direct Causation in Education

- Supposes that learning happens through:
 - singular,
 - direct causes
- Research design is built around this idea



Systemic Causation in Education

- Supposes that learning happens through:
 - a network of interconnected, probabilistic elements,
 - with built-in feedback loops.
- But how to design research to investigate this?

Network Definitions

What is a **Network**?

Collection of Object-like things that are connected.

- Nodes: Object-like things (Nouns)

- Students in a class
 - Words in a book
 - Concepts

- Can have attributes.



Network Definitions

What is a **Network**?

Collection of Object-like things that are connected.

- Ties/Edges/Links: Connections between nodes (Verbs)
 - Talked to each other
 - Are adjacent
 - Used together
- Directional
- Weighted
- Multiplex



Fundamentals of Network Analysis

Network Analysis is for the analysis of **relational data**. There are four basic assumptions:

- 1 Actors (nodes) and interactions are interdependent*
- 2 Ties (edges) all flow (information, resources, etc) between actors.
- 3 Network models on individuals both constrain and provide opportunity for individual action.
- 4 Network models conceptualize structures as representations of lasting patterns of relations between actors.



*Violates basic assumption of inferential statistics.

Ego Analyses

What can we do based on one node?

- Ego density
- Number of Neighbors
- Number of Connected Neighbors

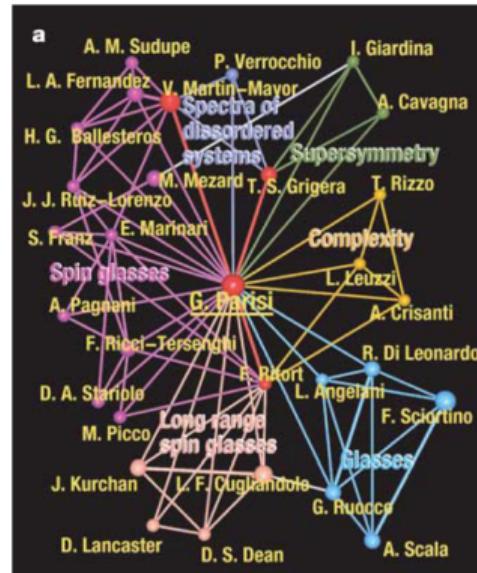


Figure: Ego Diagram for Giorgio Parisi

Node-level Analyses

Centrality - Family of metrics of importance of single node

- Degree Centrality
- Geodesic Distance (Kevin Bacon)
- PageRank
- Target Entropy

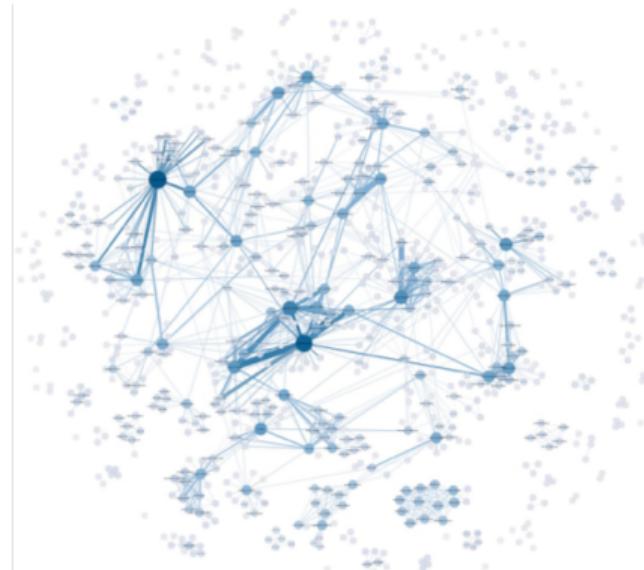


Figure: PER Citation Network

Graph-level Analyses

Analyses of whole network

- Density, Average path length, Giant component
- Clustering
- Homophily
- Modeling
 - Block modeling
 - Small World

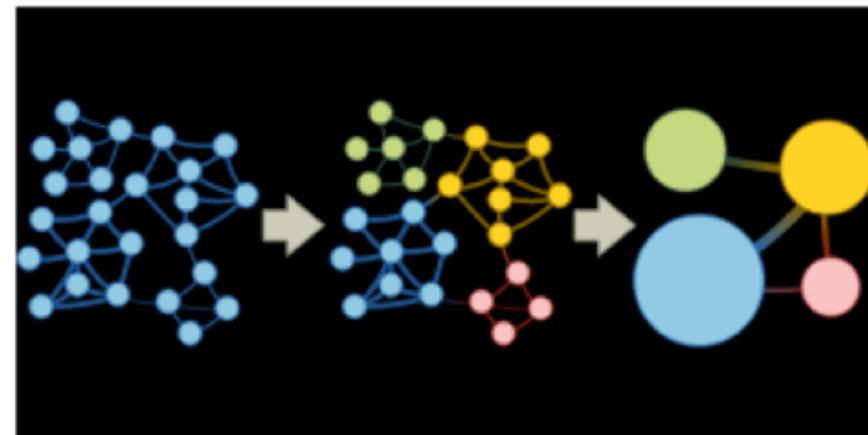


Figure: Infomap Clustering



Historical Foundations of Network Analysis

- Joseph Moreno & Helen Hall Jennings (1932)
 - Established foundations of SNA
- Quantitative Sociology/Anthropology
 - Davis Southern Women's Club (1941)
 - Small World Problem (1967)
 - Zachary's Karate Club (1977)
- Seminal Articles
 - Milgram, Stanley "The small world problem" *Psychology Today* 2:1, (1967)
 - Granovetter, Mark S. "The strength of weak ties" *American Journal of Sociology* (1973)



Modern Foundations of Network Analysis

■ Socio-physics (1990s)

- Mathematics of graph theory, applied to complex systems
- Information theory
- Computing power
- Internet
- Power Grid
- Transportation

■ Seminal Articles

- Watts & Strogatz "Collective dynamics of small world networks" *Nature* (1998)
- Page, Brin, Motwani, & Winograd "The PageRank citation ranking: Bringing order to the web" *Stanford InfoLab* (1999)



Important Takeaways from History

- Two main camps
 - Statistical - hypothesis testing
 - Graph Theoretic - network models compared with simulated data

They don't often agree, there is some open disdain. They have different languages, journals, conferences.



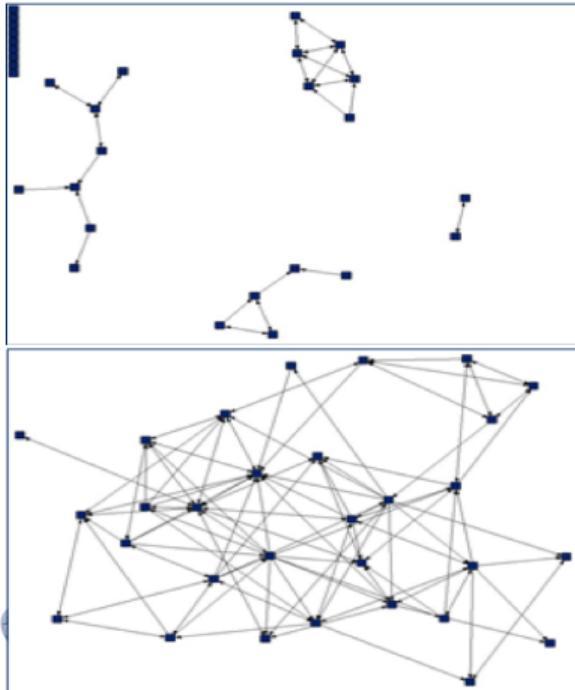
Studies of Classroom Engagement

Study #1: Pedagogy structures student engagement



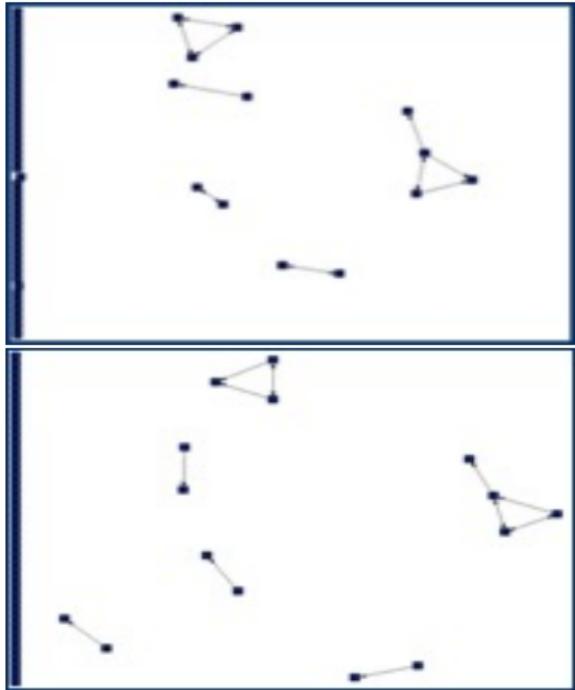
Classroom Networks in Modeling Instruction

Modeling Instruction



Pre
Post

Lecture Instruction



Studies of Classroom Engagement

Study #2: Student Networks Influence Learning



Using Centrality to Predict Grades

■ University of Copenhagen - Physics 1

- 178 Students
- Weekly Electronic Survey
 - Hvem diskuterede du fysikkconceptor med i denne uge?
 - Hvem diskuterede du fysikopgaver med i denne uge?
 - Hvem snakkede du med socialt - og altså ikke om fysik - med i forbindelse med undervisningen?



Using Centrality to Predict Grades

- University of Copenhagen - Physics 1
 - 178 Students
 - Weekly Electronic Survey
 - Whom did you discuss physics concepts with this week? (CD Network)
 - Whom did you discuss physics problems with this week? (PS Network)
 - Whom did you talk to socially – not about physics – in class this week? (ICS Network)
- Grades in Physics 1 + FCI as attributes
- Linear model to predict future grades



Using Centrality to Predict Grades

Centrality Measures

- In-degree (k_{in})
- In-Strength (s_{in})
- PageRank (PR)
- Hide (H)
- Target Entropy (T)

From: Bruun & Brewe (2013)

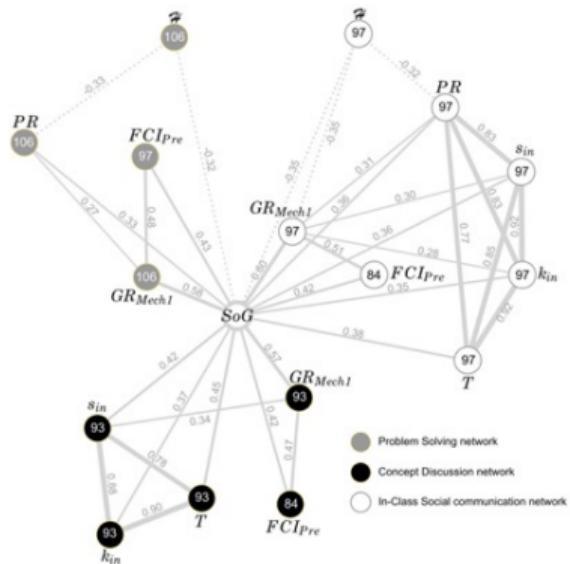


Figure: Grade Correlation Network

Using Centrality to Predict Grades

- Linear Modeling to predict grade in combined Physics II + Math in three networks (CD, PS, ICS)
 - Problem Solving Network: Grades ~ FCI Pre
 - Concept Discussion Network: Grades ~ Target Entropy
 - **In-Class Social Network: Grades ~ FCI Pre + Target Entropy + Hide**



Studies of Classroom Engagement

Study #3: Students Responses on Conceptual Inventory are Relational



Module Analysis of Multiple Choice Responses

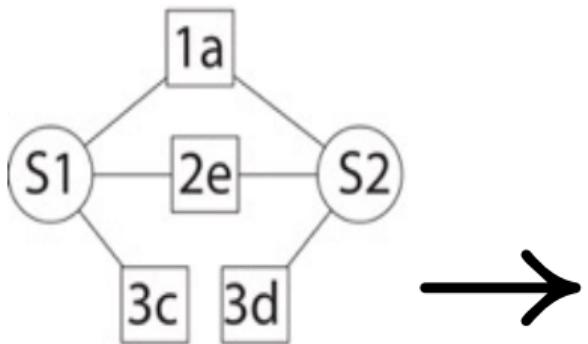
Force Concept Inventory

- Intended to be a diagnostic instrument
- Common analyses include:
 - Percent Correct
 - Normalized Gain
- Curiously reliable
- Psychometricians **HATE** it
- Factor Analysis is challenging

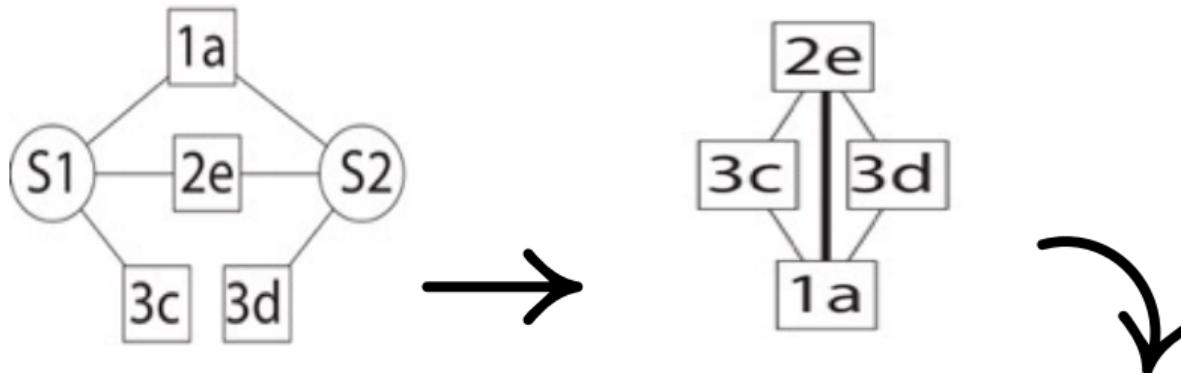


from Brewe, Bruun & Bearden (2016)

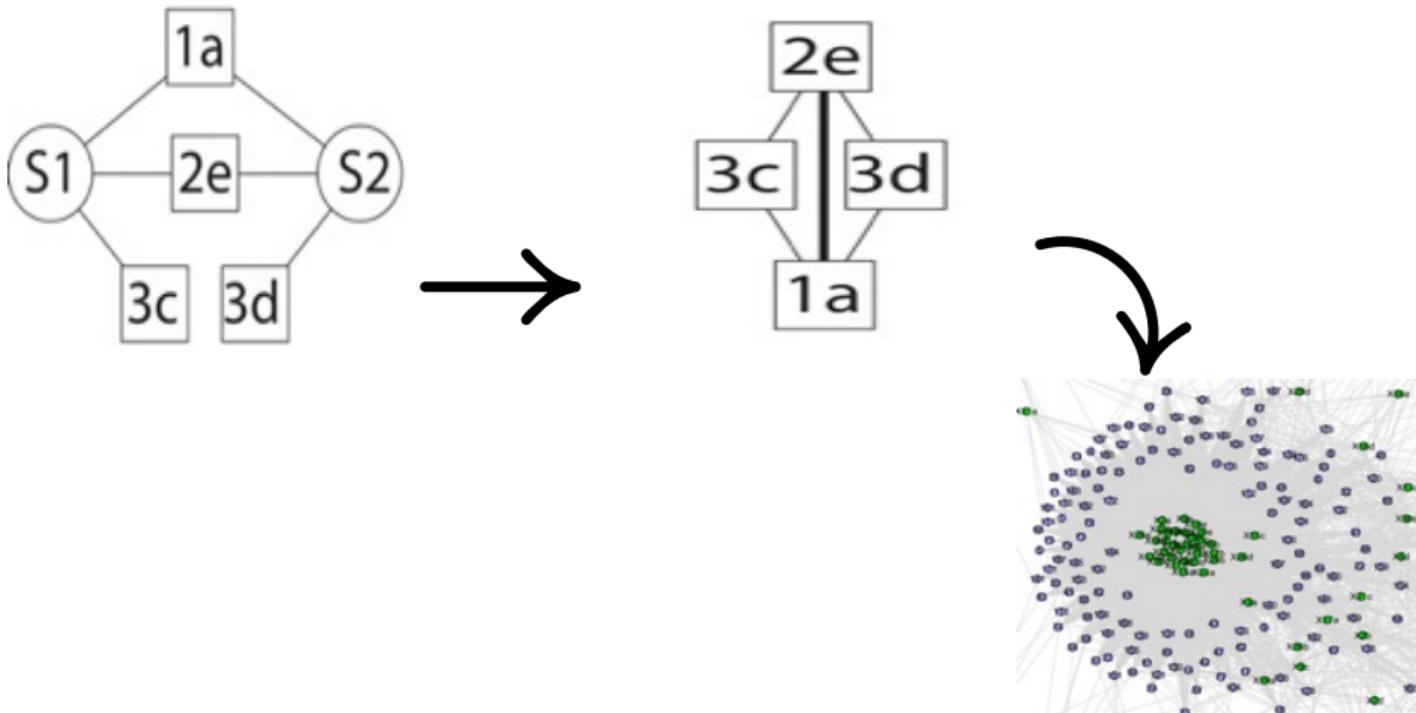
Module Analysis of Multiple Choice Responses



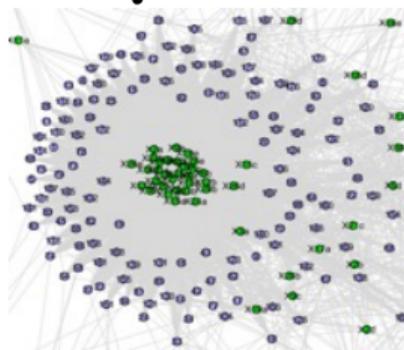
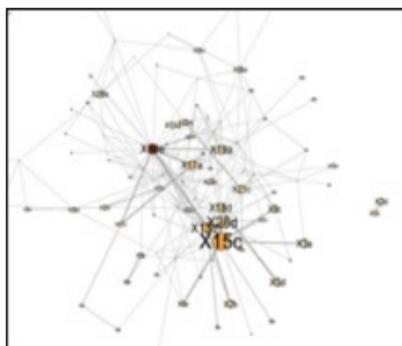
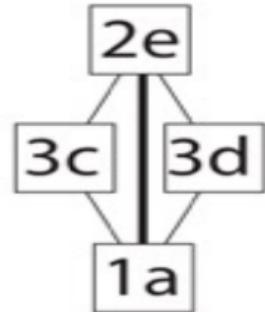
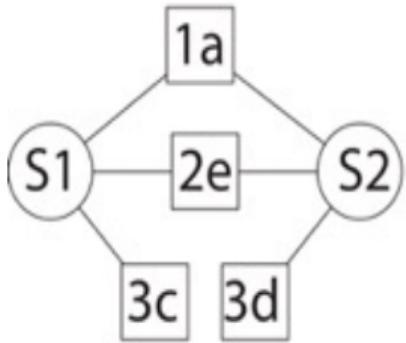
Module Analysis of Multiple Choice Responses



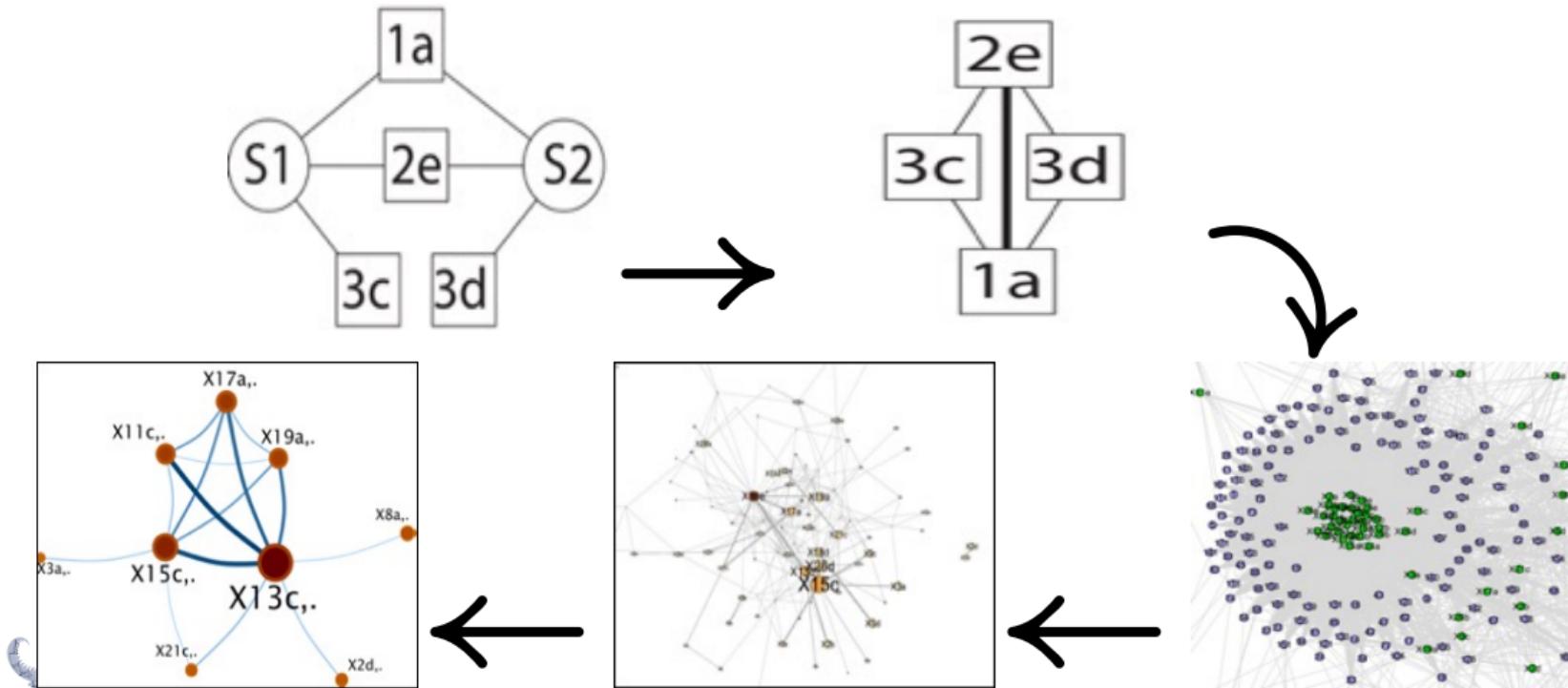
Module Analysis of Multiple Choice Responses



Module Analysis of Multiple Choice Responses



Module Analysis of Multiple Choice Responses



Interpreting a Module

Impetus Cluster

- Two primary nodes are impetus
 - Others consistent with impetus

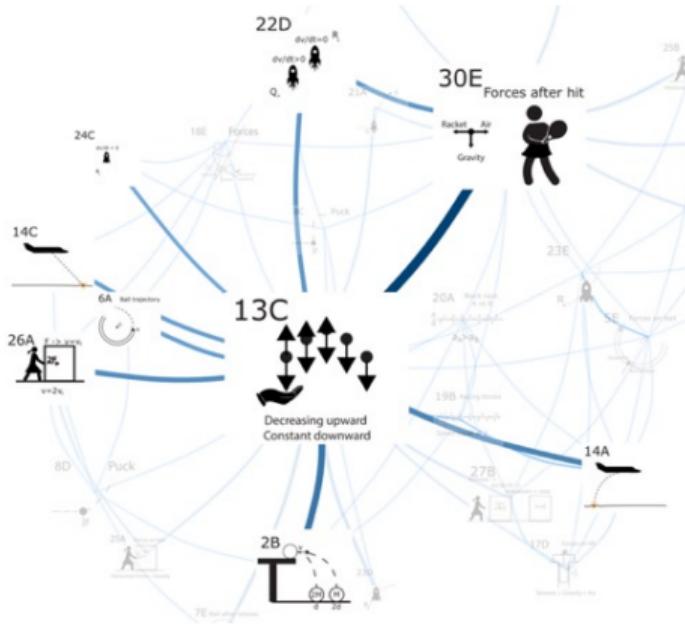


Figure: Impetus Module

Interpreting a Module

Module 3

- Constant \vec{v} requires
Constant \vec{F}
- or...is it \vec{a} and \vec{v} not
discriminated

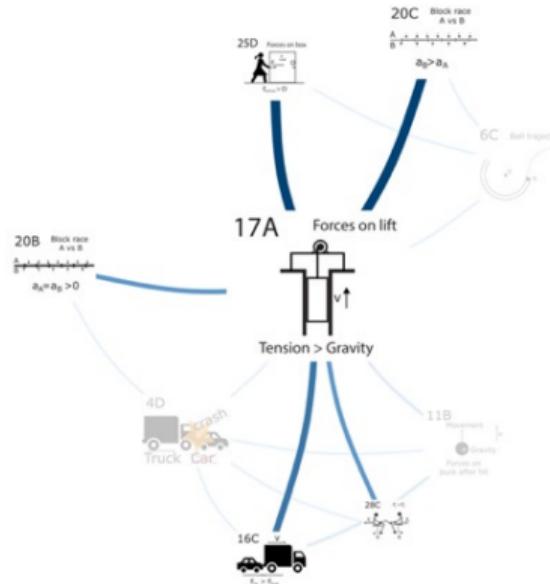


Figure: Module 3

Network Method for Analysis of Conceptual Inventory

- Data driven approach to identifying student conceptions
- Latent models are hard to interpret
- Goes beyond right/wrong



Studies Beyond Students

Study #4: Instructional Fingerprinting



Instructional Fingerprinting

Framework for Interactive Learning in Lectures (FILL) Wood et al., 2016

- Observational protocol, marks shifts between activity types, scaled by time.

Data:

- Class #1 - Instructors A, B
- Class #3 - Instructor A (different class)



Class #1 Instructors A & B

FILL Network

Course 1, Instructor A

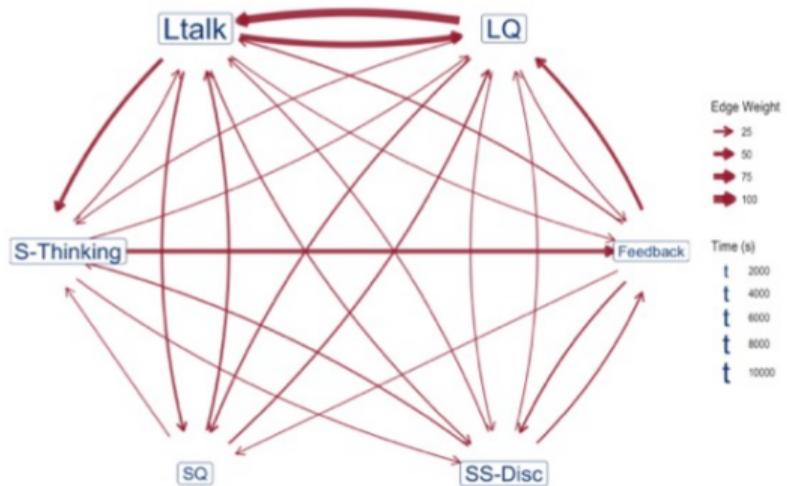


Figure: Instructor A

FILL Network

Course 1, Instructor B

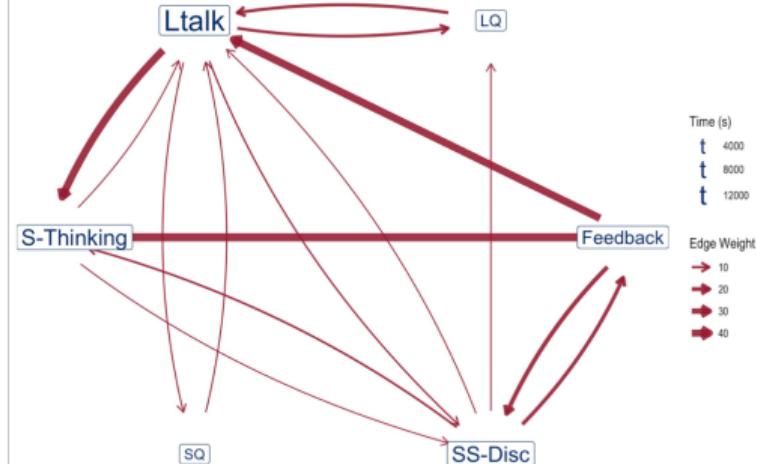


Figure: Instructor B

Instructor A, Classes 1 & 3

FILL Network

Course 1, Instructor A

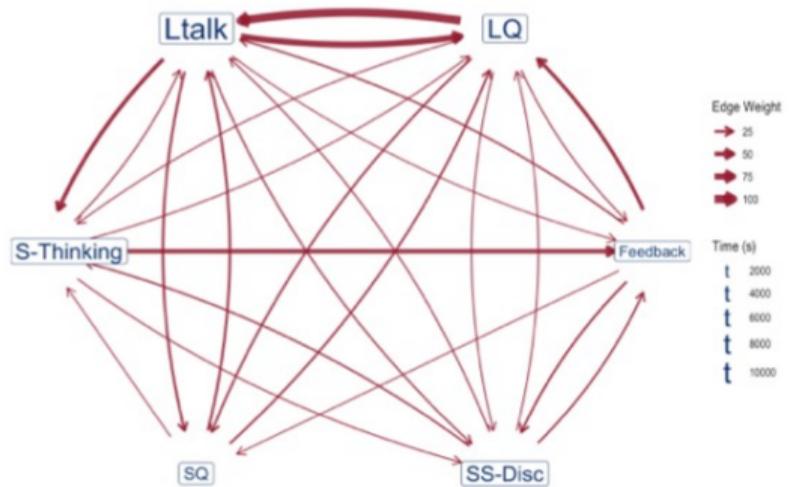


Figure: Instructor A - Course 1

FILL Network

Course 3, Instructor A

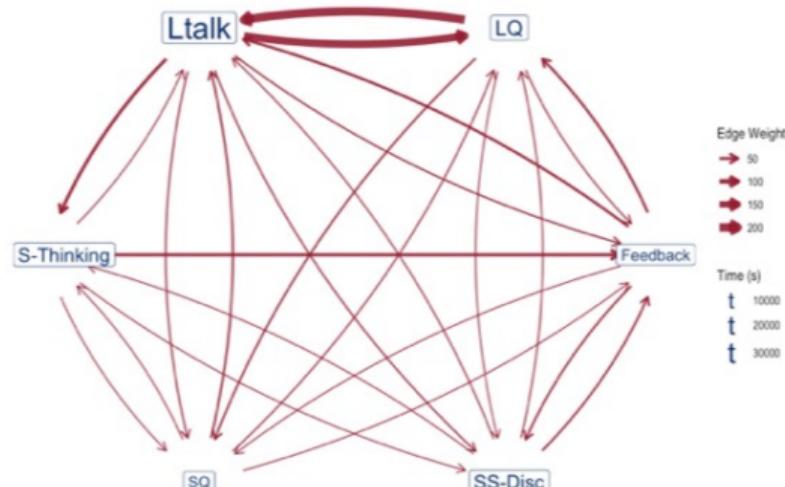


Figure: Instructor A - Course 3

Key Findings

- Useful in distinguishing pedagogies
- Reveals role of engagement in student outcomes
- Reveals latent conceptual modules in student responses
- Reveals structural patterns of interaction in teaching



Take Aways

- Network Analysis is a robust theory / methodology with wide applicability
 - Informs structure of classrooms, departments, and spaces
 - Reveals latent structure and complex dynamics
 - New direction in PER & education broadly
- Not the only tool for PER



How to design for systemic causation?

- Continue with correlational studies
 - Consider networks of causation
- Keep interactional designs in mind
 - Consider whether data are truly independent
- Design for complexity



Thank you!

