Graph-Theoretic Analysis of Interaction Networks for Enhancing Group Effectiveness

2025 Louisiana Space Consortium Annual Meeting

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Background

Why focus on groups?

- The choice of group members can have a significant impact on the success of a project
- There are few data driven methods for selecting group members
- Groupings occur in various aspects of life: Education, Research, Corporate Offices, Industrial Settings, etc.

Relevance to Nasa

- Teamwork is a core value of NASA
- The success of projects such as Artemis and CHAPEA hinge heavily on the effectiveness of the team members chosen
- Space Operations Mission Directive
- Science Mission Directive with the integration of an innovative technique from Mathematics

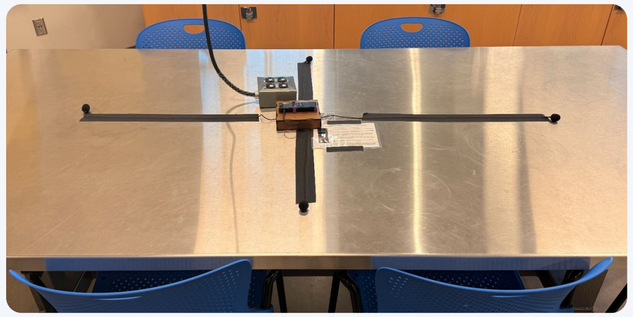
Process

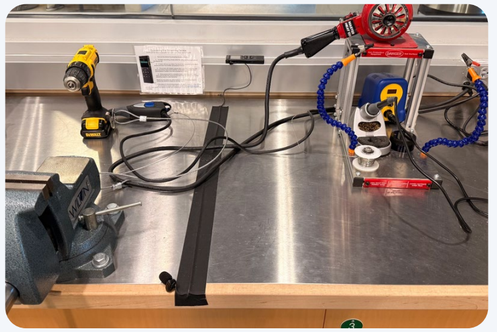
Subjects

- Students enrolled in the Honors sections for ENGR 12x2 series at Louisiana Tech University .
- At the start of the Fall 2025 quarter, this study had 135 total participants . Currently, after the final day to withdraw from the course with a ‘W’, there are **127 participants remaining** .

Audio Recording Setup

- Each classroom contains four tables of six students and six “Fabrication Stations”
- At each table, there is one audio recorder, a splitter, and five microphones
- Each fabrication station has an audio recorder and one microphone

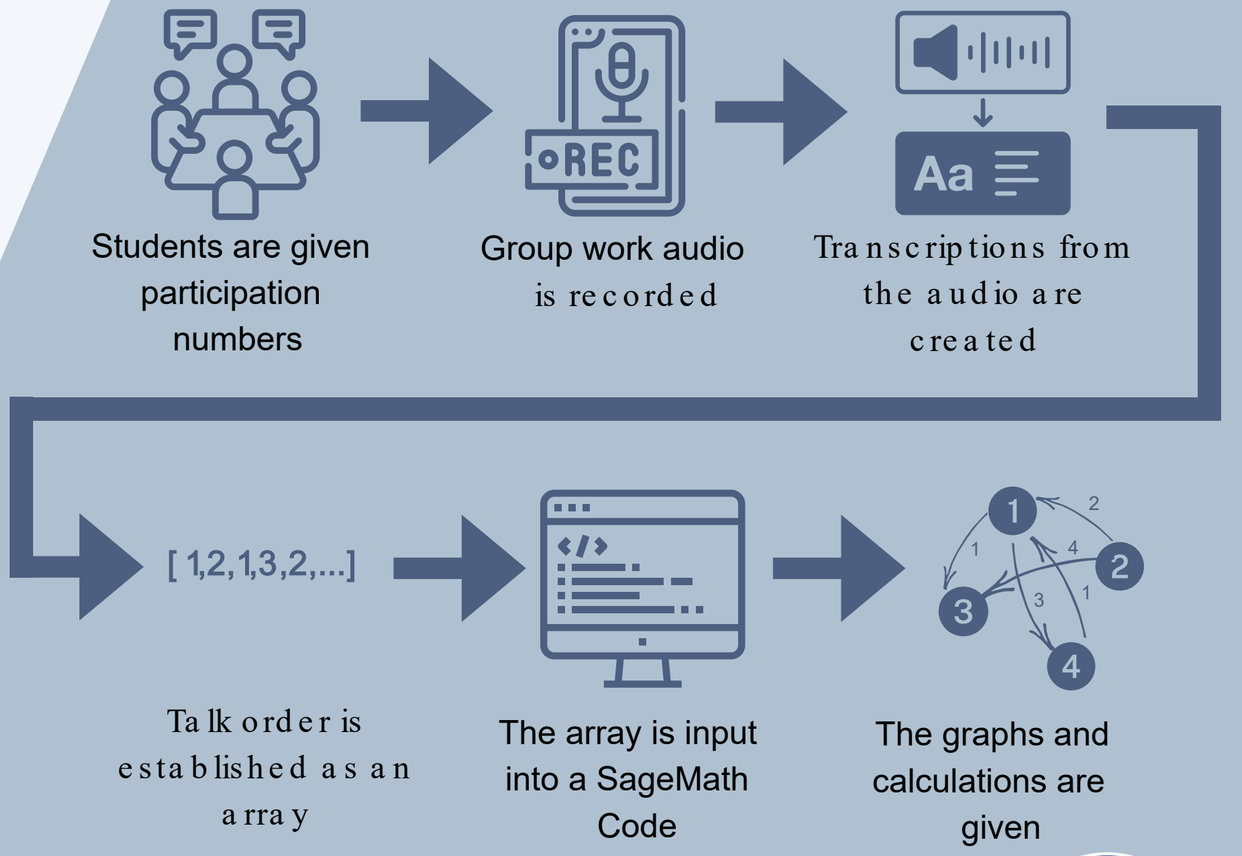




Process

Data Collection

- During each instance of group work, the students turn on the recorders, state their participation number, and proceed with group work as normal .
- Using an AI transcription software, a transcript of each audio file is created .
- From this, we can create an array for the talk order to use with SageMath to create the graphs and run calculations



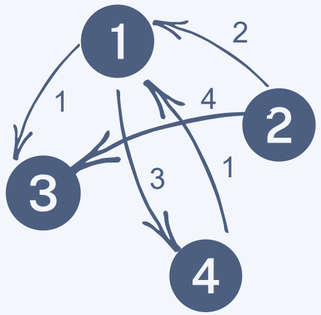
Graph Theory Model

How does a conversation turn into a graph?

Student conversations are turned into weighted bi-directional graphs using the method outlined in previous literature. [1][2]

Each student becomes a vertex of our graph. The vertices are named by the students' participation number

A directed edge is created between vertices when one student speaks after another. Referred to as a "Talk Turn"



Each "talk-turn" increases the weight on the edge

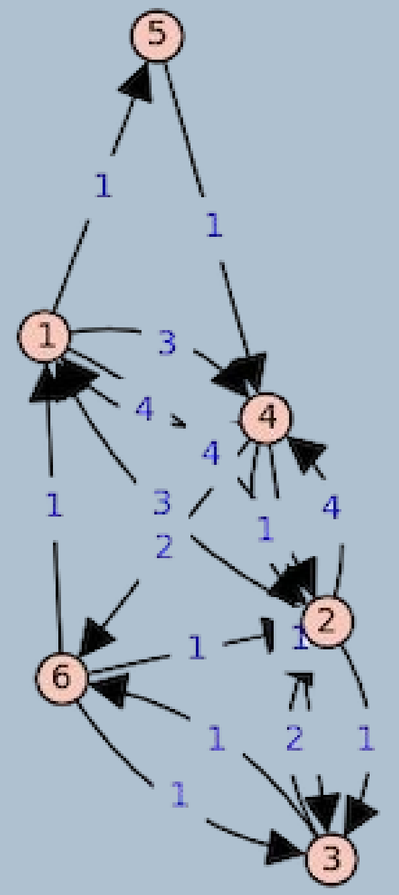
Initial Data

On average, there are one to two audio recordings of each participant a week, resulting in approximately 100 recordings available at this time .

Calculations performed on each graph:

- Degrees (in, out), centrality, and density are all common calculations in graph theory
- Talk Ratio is found by taking the degrees in for each vertex and dividing by the “fair share ratio” (sum of all degrees in divided by number of vertices). This gives a percentage that can be used to observe how many of the conversation turns each vertex took

Example of a graph generated from collected data



Degrees : [(8,8), (8,8), (3,3), (8,8), (1,1), (3,3)]
Centrality : [16 , 16 , 6 , 16 , 2 , 6]
Talk Ratio : (%):[154 , 154 , 58 , 154 , 19 , 58]
Density (%): 53 .3

Observations

**As data collection is still in its early stages, these are strictly prelimary observations from a smaller subset of available graphs*

Group Perspective

Density appears to be a strong indicator of how the group as a whole communicates. Higher density percentage shows that the individuals are speaking to more of their group mates and that the conversation is flowing in both directions

Individual Participant Perspective

Centrality can reveal how critical an individual is to the flow of the conversation and **talk ratio** has been useful to observe what percentage of the overall turns in conversation an individual was responsible for. Both give insight to the communication style of the indivudal

Future Work

Fall 2025

Analyzing connections between current student groups. Identifying key characteristics

Winter ‘25 - ’26

New groups will be formed. Identify if the characteristics from previous quarter carry over

Spring 2026

Students form freshman design project groups. Analyze in class group work

Data Collection Continuing

Beyond

Compare graphs and individual vertex characteristics with judges showcase score cards, group member surveys, instructor scores, and instructor surveys from the first year design showcase projects. From these, draw data based conclusions on group efficacy

Thank You

Questions?

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[1] Chai, Albert, et al. "Applying Graph Theory to Examine the Dynamics of Student Discussions in Small-Group Learning." CBE-Life Sciences Education, no. 18, The American Society for Cell Biology, June 2019, pp. 1-12.

[2] Siddiqui, Asfar H., et al. "Exploring the Dynamics of Educational Feedback Networks with Graph Theory and LSTM-Based Modeling for Enhanced Learning Analytics and Feedback Mechanisms." Journal of Theoretical and Applied Information Technology, no. 102, Little Lion Scientific, Jan. 2024, pp. 111-22.