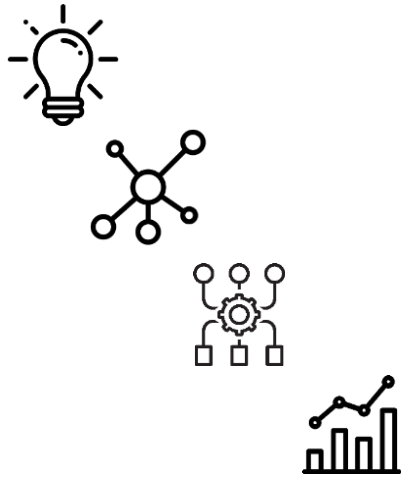
# Analytics for Classroom Social Networks

## Outline:

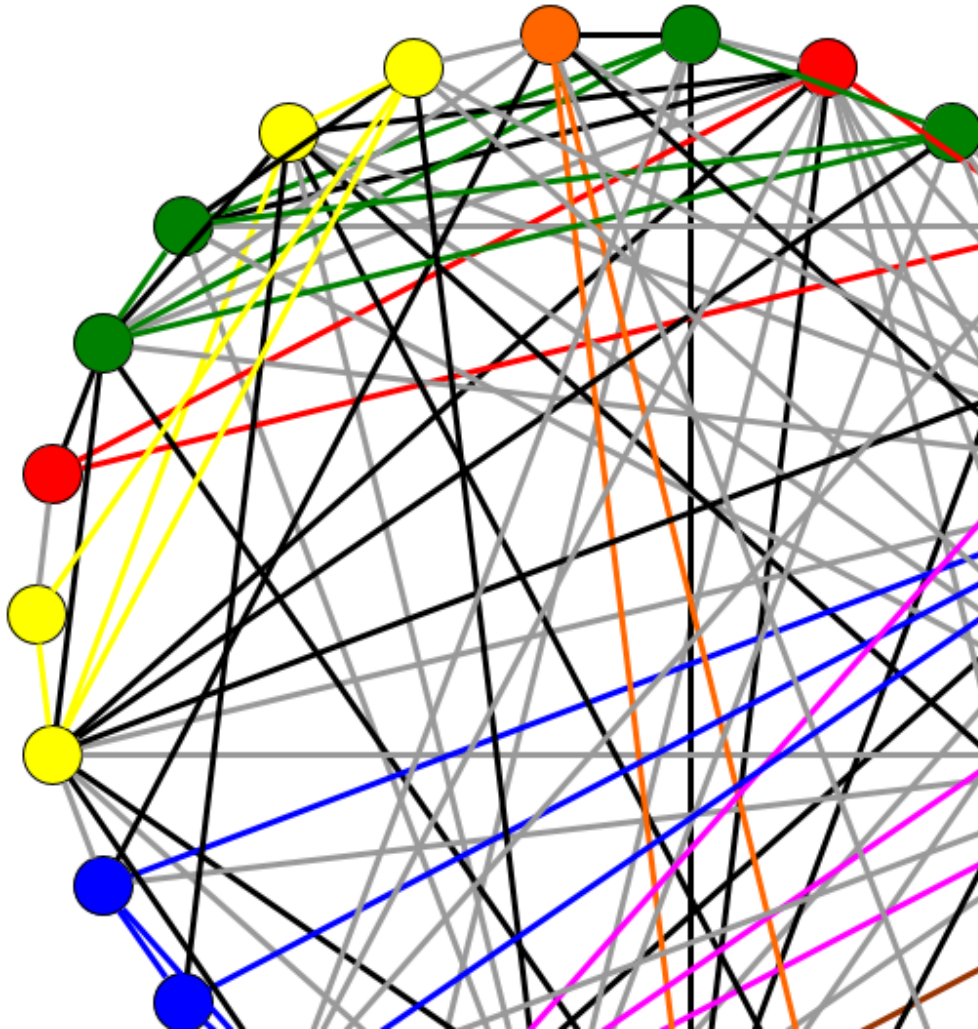
**A. Project Teams**

1. Motivation & Idea
2. Class Social Network
3. Optimization Model
4. Results & Analysis
5. Conclusion



**B. Seating Arrangements**

**C. Rotational Grouping**



## Joint work with:

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California Polytechnic State University, CA

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Management Science & Technology
Athens University of Economics & Business
Greece

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Los Alamitos, CA

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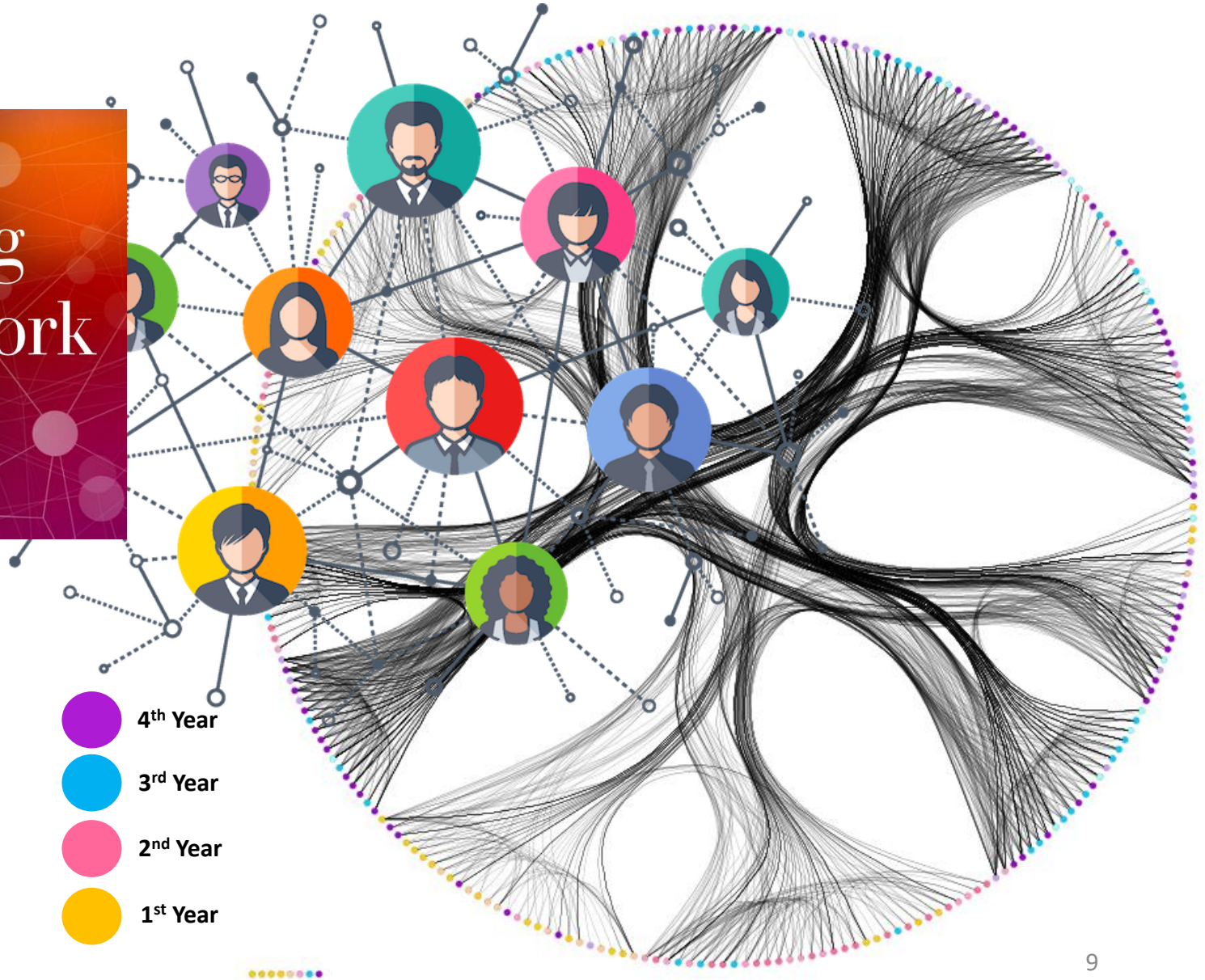
# Motivation

**Question:** How many other students do your students "know" in your program?

## An Analysis of the Industrial Engineering Students' Social Network

Gianna Nobili, Dr. Alessandro Hill, Davey Hom

Cal Poly SLO Industrial and Manufacturing Engineering Department

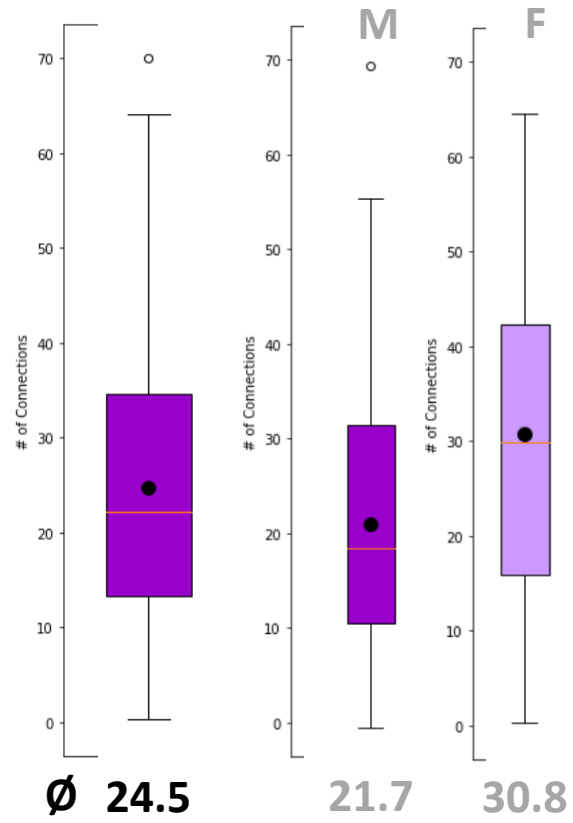



**Industrial Engineering Majors in Winter 2023**

- **272 Students**
- **2237 Ties**
- **Density: 0.061**
- **Max Clique Size: 12**
- **Diameter: 7**
- **Average Betweenness: 0.0056**
- **Average Closeness: 0.37**
- **Average #Connections: 16.4**

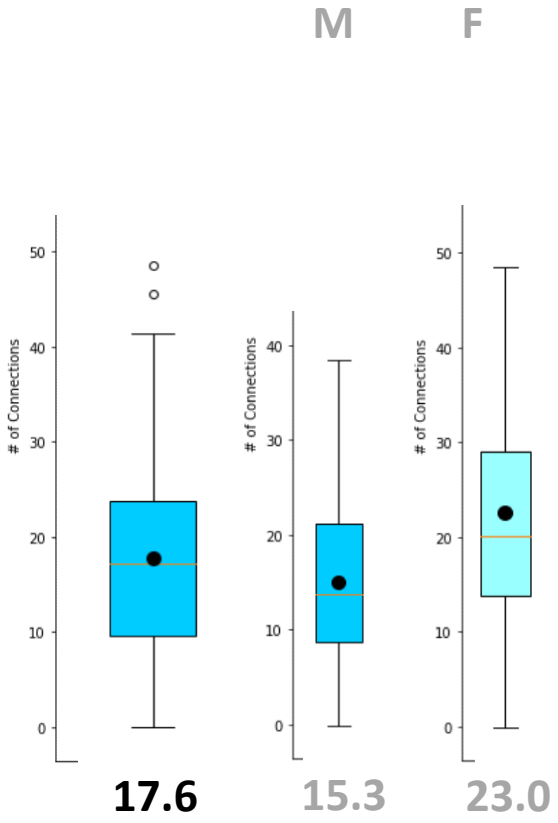
# Overall Social Network in IE @ Cal Poly

**4th Year**



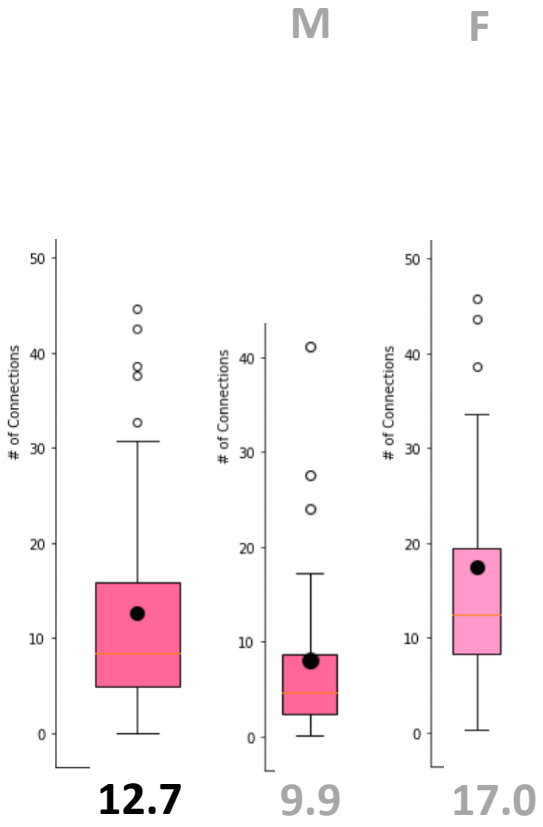

Ø 24.5 21.7 30.8

**3rd Year**



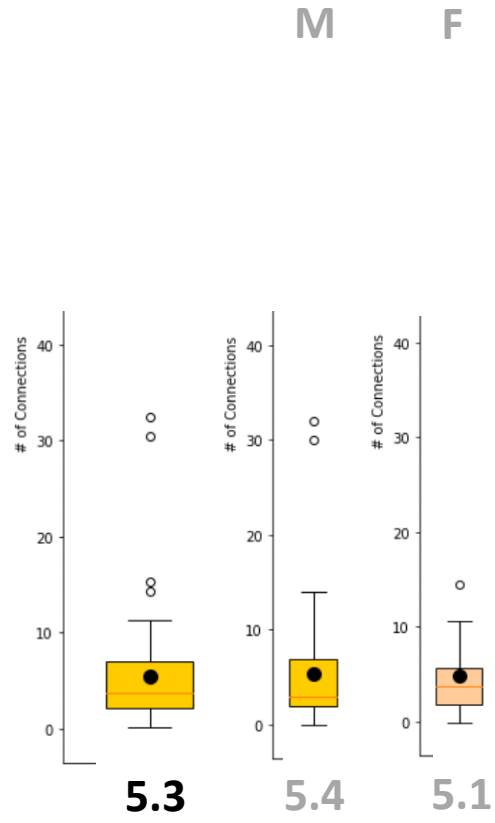

17.6 15.3 23.0

**2nd Year**



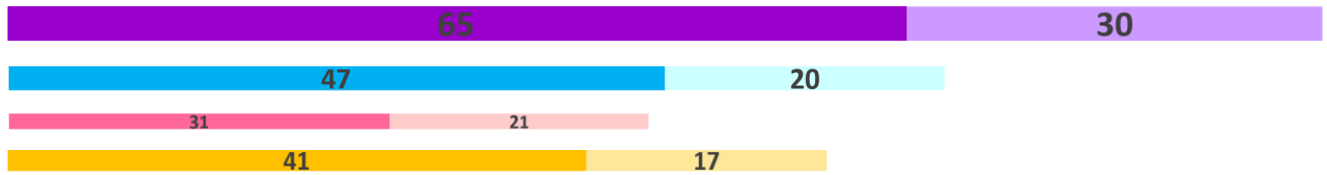

12.7 9.9 17.0

**1st Year**




5.3 5.4 5.1

**Number of Students:**

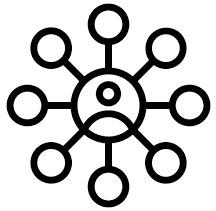


# Motivation

**Facts:**

- A student's social connections are very important.

**Networking** **Inclusion** **Mental Wellbeing** **Academic Success** **. . .**



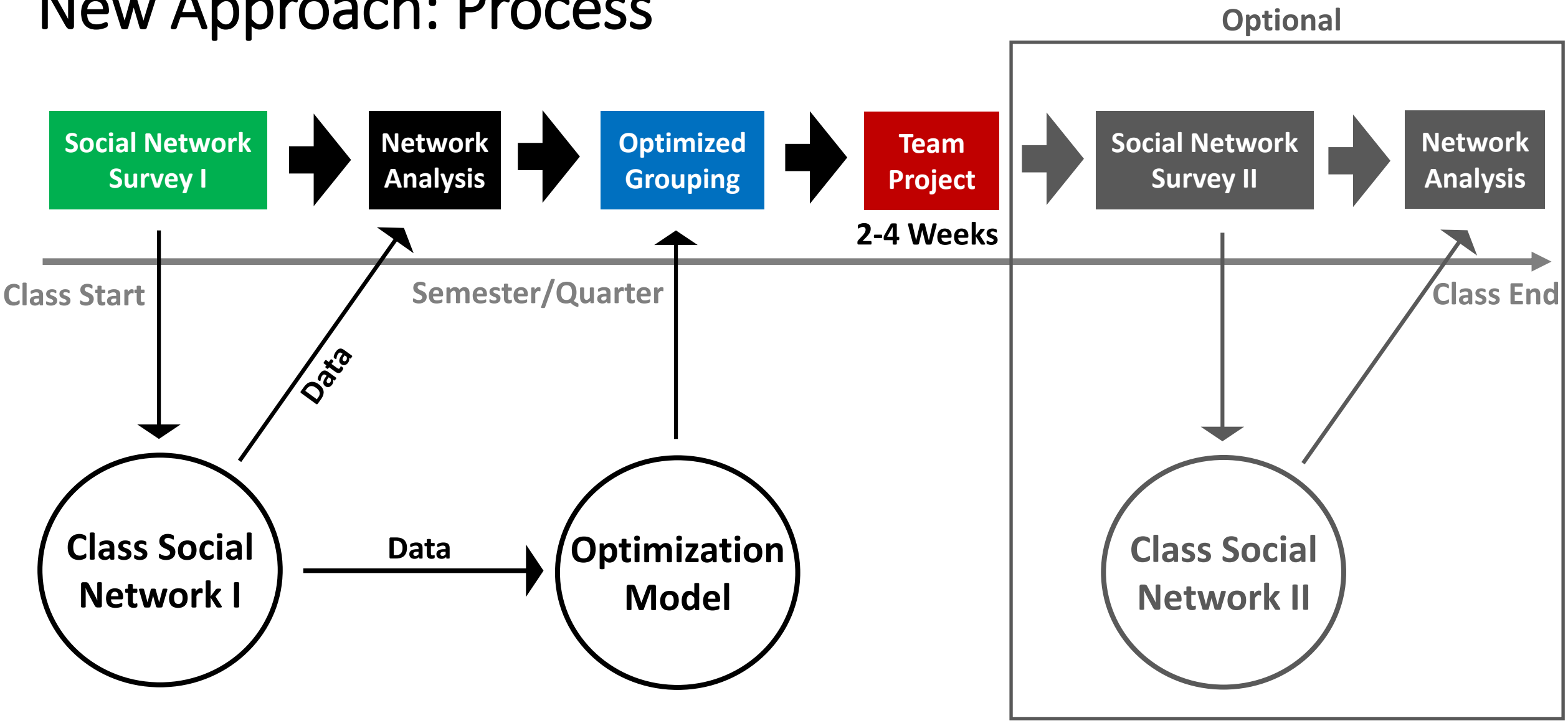

- Connections are created via collaboration.

**Idea:** Group students aiming at a maximum number of new ties!

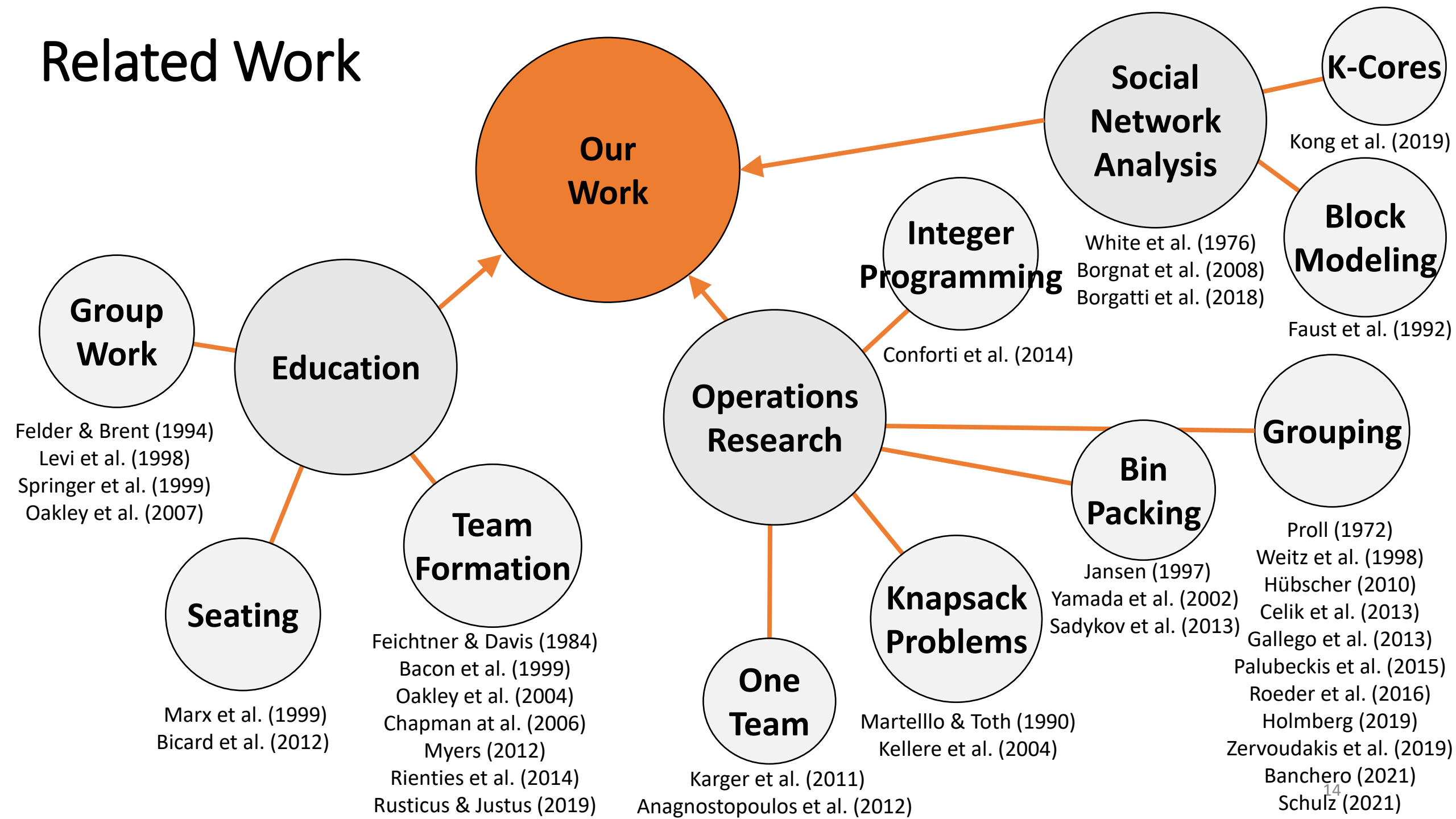
**Questions: Given a university course with a student team project . . .**

1) **Can we team students to foster new connections?**
2) **What techniques do we need?**
3) **How effective is this in practice?**

# New Approach: Process



# Related Work



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# Relationship & Data Collection

"Please insert an X for the people that you know. Knowing someone means to have worked with the person or have repeatedly interacted with this person beyond surface-level."

## Survey Data

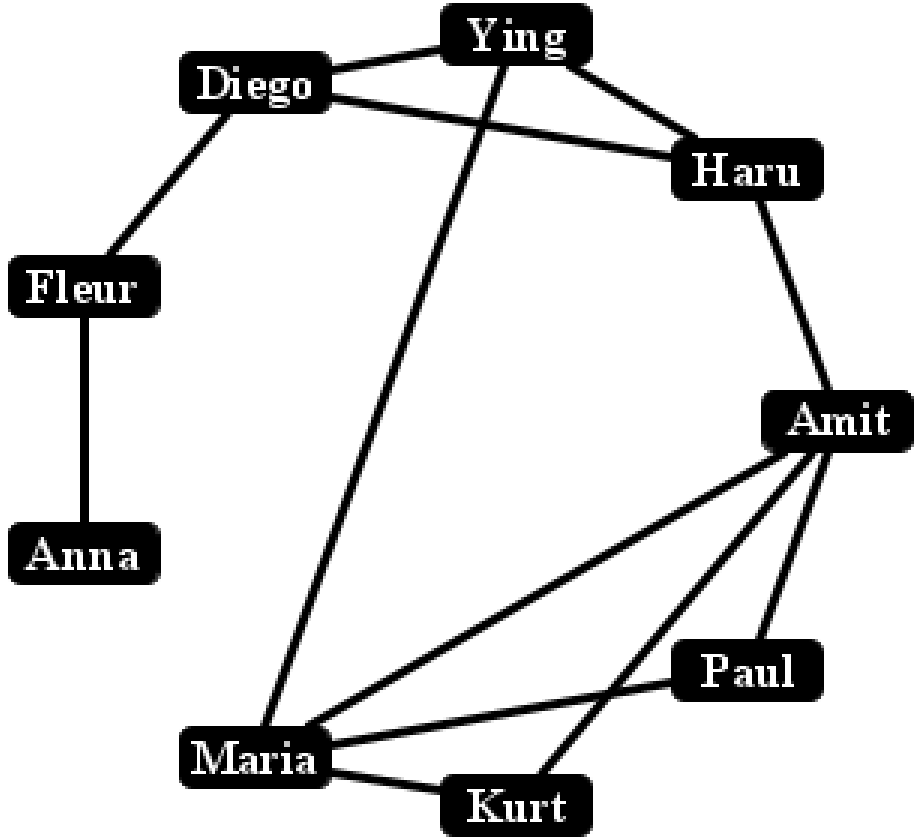
### Individual Response

| # | Name | 1 Anna | 2 Amit | 3 Fleur | 4 Diego | 5 Haru | 6 Maria | 7 Paul | 8 Kurt | 9 Ying |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Anna | | | | | | | | | |
| 2 | Amit | | | | | | | | | |
| 3 | Fleur | | | | | | | | | |
| 4 | Diego | | | | | | | | | |
| 5 | Haru | | | | | | | | | |
| 6 | Maria | | X | | | | | X | X | X |
| 7 | Paul | | | | | | | | | |
| 8 | Kurt | | | | | | | | | |
| 9 | Ying | | | | | | | | | |

### Adjacency Matrix

| # | Name | 1 Anna | 2 Amit | 3 Fleur | 4 Diego | 5 Haru | 6 Maria | 7 Paul | 8 Kurt | 9 Ying |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Anna | | | X | | | | | | |
| 2 | Amit | | | | | X | X | X | X | |
| 3 | Fleur | X | | | X | | | | | |
| 4 | Diego | | | X | | X | | | | X |
| 5 | Haru | | X | | X | | | | | X |
| 6 | Maria | | X | | | | | X | X | X |
| 7 | Paul | | X | | | | X | | | |
| 8 | Kurt | | X | | | | X | | | |
| 9 | Ying | | | | X | X | X | | | |

## Class Social Network



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# An Integer Programming Formulation for the Social Student Team Assignment Problem*

*$NP$-hard

$$x_{i,k} = \begin{cases} 0 & \text{if node } i \text{ is not assigned to team } k \\ 1 & \text{if node } i \text{ is assigned to team } k \end{cases} \qquad \forall\, i \in N \qquad \forall\, k \in M$$

$$y_{i,j} = \begin{cases} 0 & \text{if nodes } i \text{ and } j \text{ are not assigned to the same team} \\ 1 & \text{if nodes } i \text{ and } j \text{ are assigned to the same team} \end{cases} \qquad \forall \{i, j\} \in E$$

$$Minimize \quad \sum_{\{i,j\} \in E} y_{i,j}$$

***Minimize Intra-Team Ties***

$$Subject\ to \quad \sum_{k \in M} x_{i,k} = 1 \qquad \forall i \in N$$

***Unique Team Assignment***

$$u_k \leq \sum_{i \in N} x_{i,k} \leq o_k \qquad \forall k \in M$$

***Team Capacities***

$$x_{i,k} + x_{j,k} \leq y_{i,j} + 1 \qquad \forall \{i, j\} \in E, k \in M$$

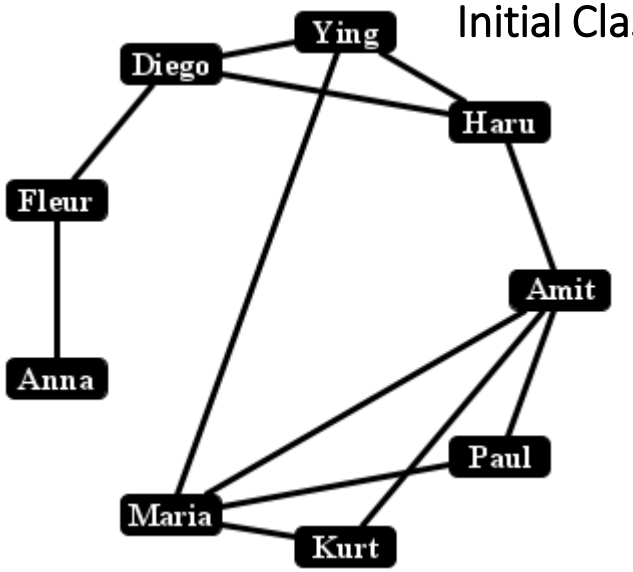
***Variable Linking***

# Example Class: Optimal Assignment

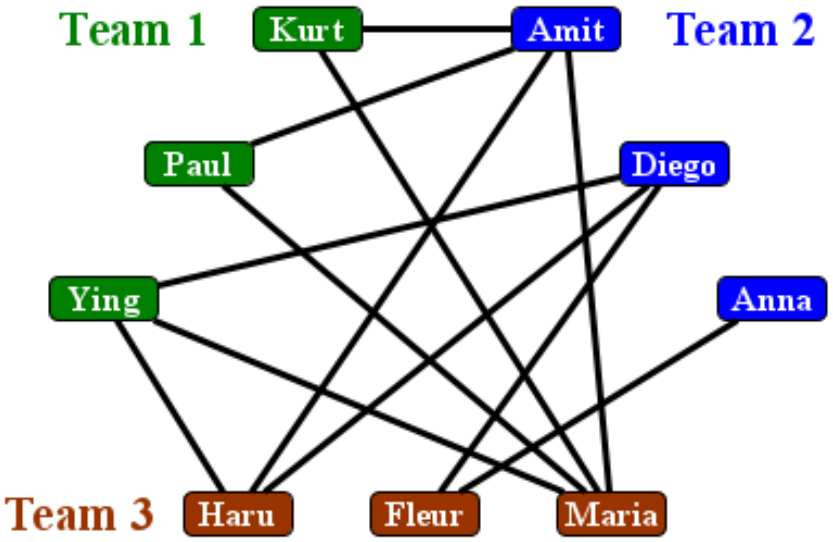
## Integer Program

```
/*Objective (1)*/
MINIMIZE y_{1,3} + y_{2,5} + y_{2,6} + y_{2,7} + y_{2,8} + y_{3,4} + y_{4,5} + y_{4,9} + y_{5,9} + y_{6,7} + y_{6,8} + y_{6,9}

SUBJECT TO

/*Equation (2)*/
x_{1,1} + x_{1,2} + x_{1,3} = 1          x_{4,1} + x_{4,2} + x_{4,3} = 1          x_{7,1} + x_{7,2} + x_{7,3} = 1
x_{2,1} + x_{2,2} + x_{2,3} = 1          x_{5,1} + x_{5,2} + x_{5,3} = 1          x_{8,1} + x_{8,2} + x_{8,3} = 1
x_{3,1} + x_{3,2} + x_{3,3} = 1          x_{6,1} + x_{6,2} + x_{6,3} = 1          x_{9,1} + x_{9,2} + x_{9,3} = 1

/*Inequality (3)*/
x_{1,1} + x_{2,1} + x_{3,1} + x_{4,1} + x_{5,1} + x_{6,1} + x_{7,1} + x_{8,1} + x_{9,1} >= 3
x_{1,2} + x_{2,2} + x_{3,2} + x_{4,2} + x_{5,2} + x_{6,2} + x_{7,1} + x_{8,1} + x_{9,1} >= 3
x_{1,3} + x_{2,3} + x_{3,3} + x_{4,3} + x_{5,3} + x_{6,3} + x_{7,3} + x_{8,3} + x_{9,3} >= 3

/*Inequality (3)*/
x_{1,1} + x_{2,1} + x_{3,1} + x_{4,1} + x_{5,1} + x_{6,1} + x_{7,1} + x_{8,1} + x_{9,1} <= 3
x_{1,2} + x_{2,2} + x_{3,2} + x_{4,2} + x_{5,2} + x_{6,2} + x_{7,1} + x_{8,1} + x_{9,1} <= 3
x_{1,3} + x_{2,3} + x_{3,3} + x_{4,3} + x_{5,3} + x_{6,3} + x_{7,3} + x_{8,3} + x_{9,3} <= 3

/*Inequality (4)*/
x_{1,1} + x_{3,1} <= y_{1,3} + 1          x_{1,2} + x_{3,2} <= y_{1,3} + 1          x_{1,3} + x_{3,3} <= y_{1,3} + 1
x_{2,1} + x_{5,1} <= y_{2,5} + 1          x_{2,2} + x_{5,2} <= y_{2,5} + 1          x_{2,3} + x_{5,3} <= y_{2,5} + 1
x_{2,1} + x_{6,1} <= y_{2,6} + 1          x_{2,2} + x_{6,2} <= y_{2,6} + 1          x_{2,3} + x_{6,3} <= y_{2,6} + 1
x_{2,1} + x_{7,1} <= y_{2,7} + 1          x_{2,2} + x_{7,2} <= y_{2,7} + 1          x_{2,3} + x_{7,3} <= y_{2,7} + 1
x_{2,1} + x_{8,1} <= y_{2,8} + 1          x_{2,2} + x_{8,2} <= y_{2,8} + 1          x_{2,3} + x_{8,3} <= y_{2,8} + 1
x_{3,1} + x_{4,1} <= y_{3,4} + 1          x_{3,2} + x_{4,2} <= y_{3,4} + 1          x_{3,3} + x_{4,3} <= y_{3,4} + 1
x_{4,1} + x_{5,1} <= y_{4,5} + 1          x_{4,2} + x_{5,2} <= y_{4,5} + 1          x_{4,3} + x_{5,3} <= y_{4,5} + 1
x_{4,1} + x_{9,1} <= y_{4,9} + 1          x_{4,2} + x_{9,2} <= y_{4,9} + 1          x_{4,3} + x_{9,3} <= y_{4,9} + 1
x_{5,1} + x_{9,1} <= y_{5,9} + 1          x_{5,2} + x_{9,2} <= y_{5,9} + 1          x_{5,3} + x_{9,3} <= y_{5,9} + 1
x_{6,1} + x_{7,1} <= y_{6,7} + 1          x_{6,2} + x_{7,2} <= y_{6,7} + 1          x_{6,3} + x_{7,3} <= y_{6,7} + 1
x_{6,1} + x_{8,1} <= y_{6,8} + 1          x_{6,2} + x_{8,2} <= y_{6,8} + 1          x_{6,3} + x_{8,3} <= y_{6,8} + 1

/*Variables (5)*/
bin x_{1,1}          bin x_{3,1}          bin x_{5,1}          bin x_{7,1}          bin x_{9,1}
bin x_{1,2}          bin x_{3,2}          bin x_{5,2}          bin x_{7,2}          bin x_{9,2}
bin x_{1,3}          bin x_{3,3}          bin x_{5,3}          bin x_{7,3}          bin x_{9,3}
bin x_{2,1}          bin x_{4,1}          bin x_{6,1}          bin x_{8,1}
bin x_{2,2}          bin x_{4,2}          bin x_{6,2}          bin x_{8,2}
bin x_{2,3}          bin x_{4,3}          bin x_{6,3}          bin x_{8,3}

/*Variables (6)*/
bin y_{1,3}          bin y_{2,7}          bin y_{4,5}          bin y_{6,7}
bin y_{2,5}          bin y_{2,8}          bin y_{4,9}          bin y_{6,8}
bin y_{2,6}          bin y_{3,4}          bin y_{5,9}          bin y_{6,9}
```

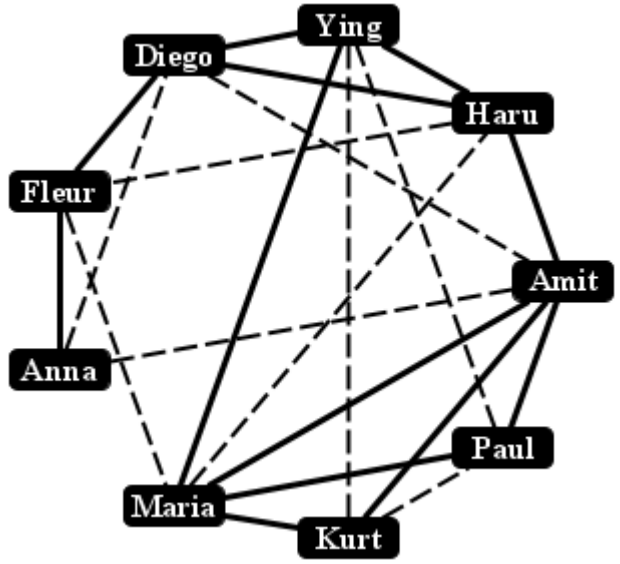
Initial Class Social Network
|E|=12




Optimal Grouping
y*=0




Post-Project Network*
|E|=21 (+75%)




*Potential

# Model Extensions

- Student Pre-Assignment
- Team Balancing
- Diversification
- Forcing/Forbidding Teammates
- . . .

→ Integration of Practical Requirements

→ Hybridization with Existing Methods

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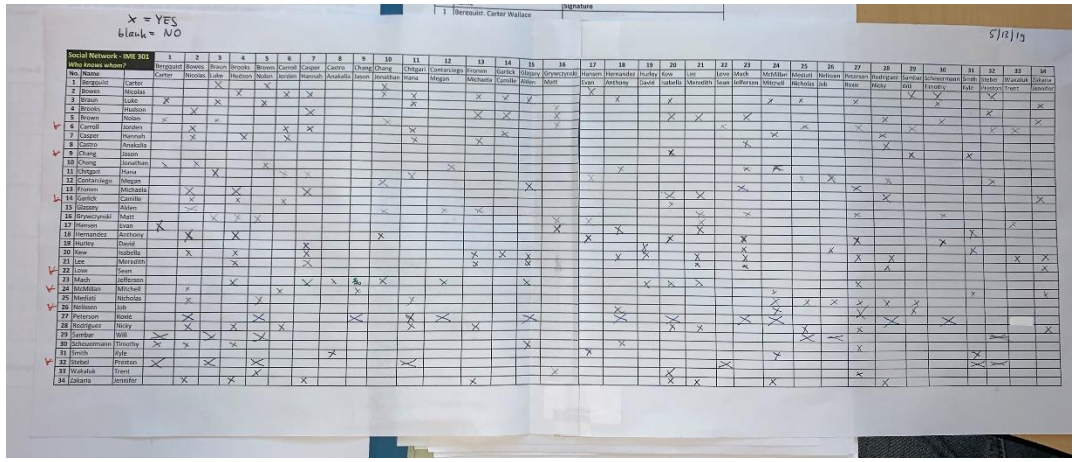
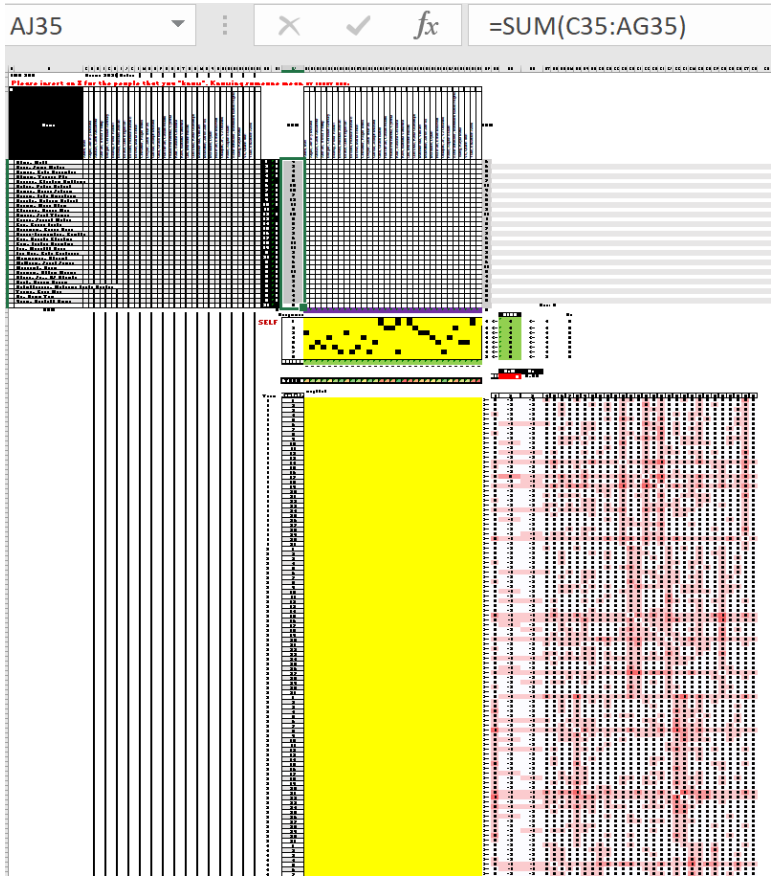
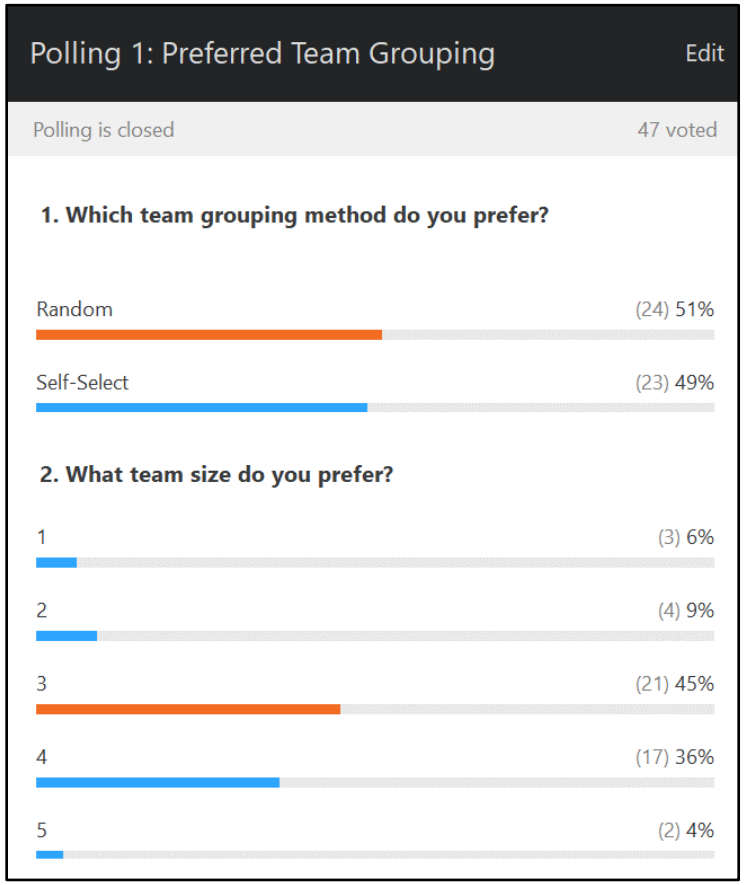
# Experiment Setup

- 10 Industrial Engineering classes (2019/20)
- Survey twice: Course start and end
- 4 Control classes allowing “self-grouping”
- Complete tie symmetrization
- Spreadsheet-based approach
- Gurobi 9.1.0 via OpenSolver

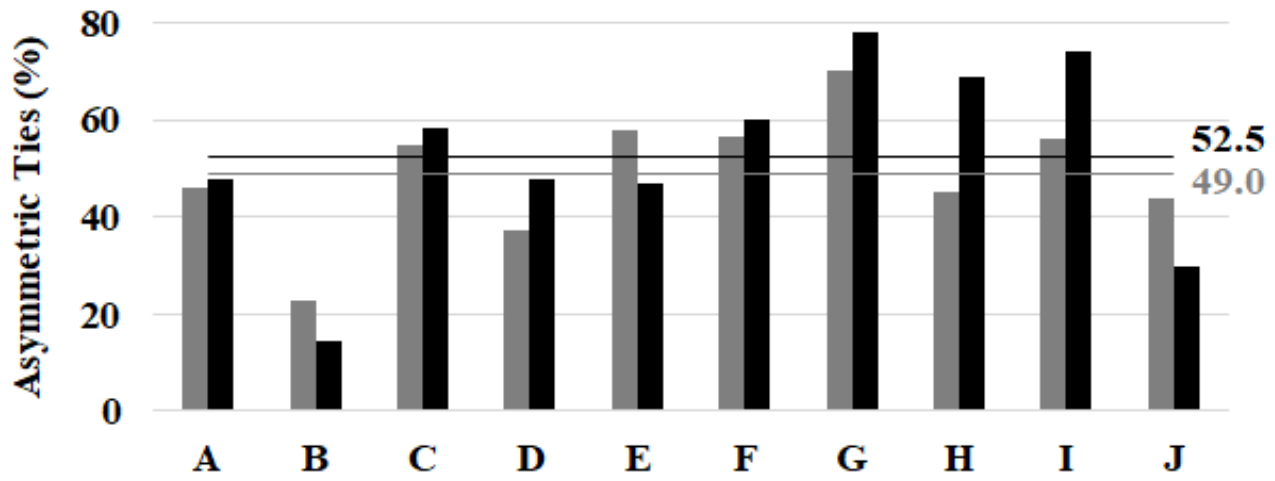


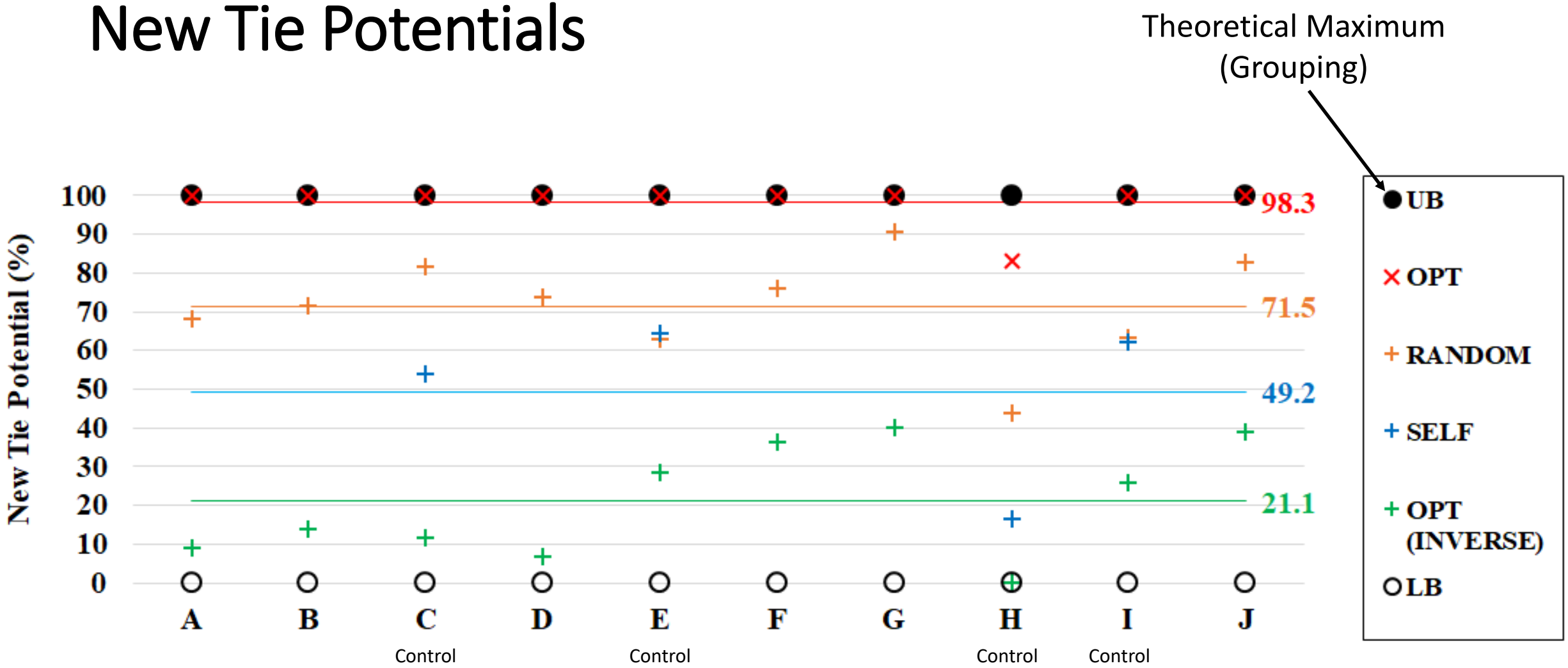



# Survey Data

| # | Term | Course | Class Mode | n | $RR_0$ | $RR_1$ | #Groups | $s_{min}$ | $s_{avg}$ | $s_{max}$ | Method |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 1 | IME 420 | Face-To-Face | 31 | 100.0 | 87.1 | 8 | 3 | 3.9 | 4 | OPT |
| B | 2 | IME 420 | Face-To-Face | 26 | 100.0 | 100.0 | 7 | 3 | 3.7 | 4 | OPT |
| C | 2 | IME 305 | Face-To-Face | 28 | 85.7 | 71.4 | 10 | 2 | 2.8 | 3 | SELF |
| D | 2 | IME 305 | Face-To-Face | 30 | 76.7 | 86.7 | 10 | 3 | 3.0 | 3 | OPT |
| E | 3 | IME 420 | Virtual | 28 | 100.0 | 85.7 | 7 | 4 | 4.0 | 4 | SELF |
| F | 3 | IME 420 | Virtual | 25 | 100.0 | 84.0 | 7 | 3 | 3.6 | 4 | OPT |
| G | 3 | IME 356 | Virtual | 20 | 70.0 | 55.0 | 10 | 2 | 2.0 | 2 | OPT |
| H | 3 | IME 541 | Virtual | 9 | 100.0 | 66.7 | 4 | 2 | 2.3 | 3 | SELF |
| I | 4 | IME 420 | Virtual | 30 | 90.0 | 93.3 | 7 | 4 | 4.3 | 5 | SELF |
| J | 4 | IME 305 | Virtual | 26 | 92.3 | 92.3 | 7 | 3 | 3.9 | 4 | OPT |
| All | | | | 253 | 91.5 | 82.2 | 77 | 2 | 3.3 | 5 | |



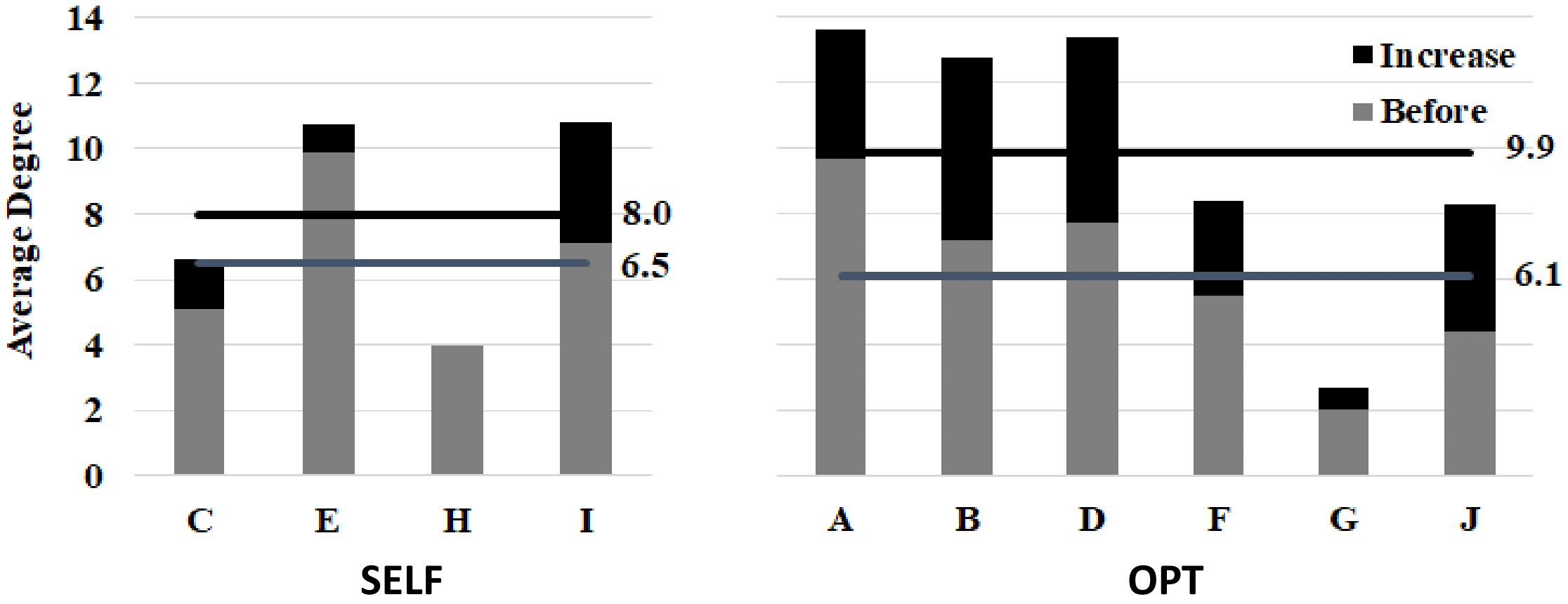
# New Tie Potentials




+ Monte-Carlo Simulation Study

+ Maximize Intra-Team Ties (Optimization)

# Actual Impact: Degree Increase



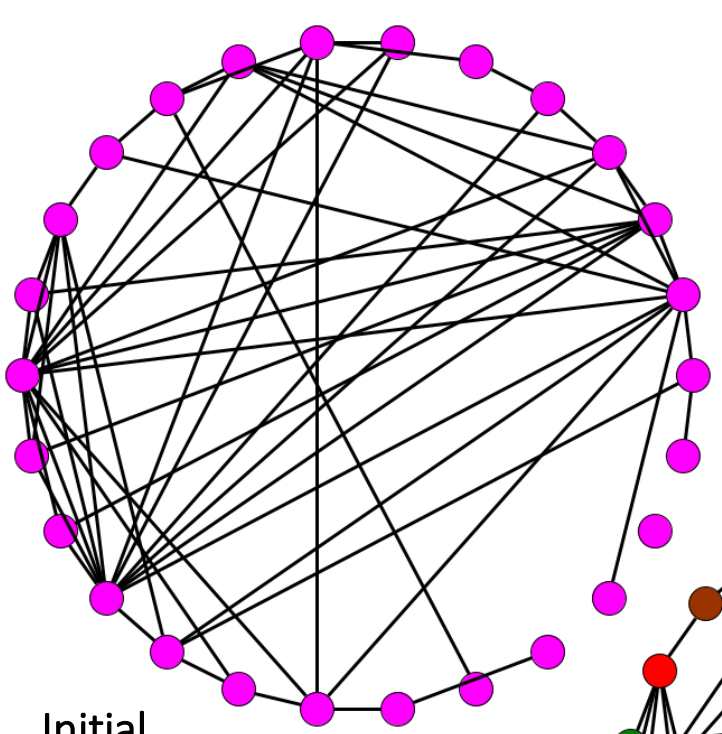
# Overall Impact

| Increase of Student Ties (%) | | | Factor |
|---|---|---|---|
| **Mode** | **SELF** | **OPT** | |
| **Face-to-Face** | 31.0 | 64.1 | x2.1 |
| **Virtual** | 12.2 | 58.9 | x4.8 |
| **All** | 16.9 | 61.5 | x3.6 |

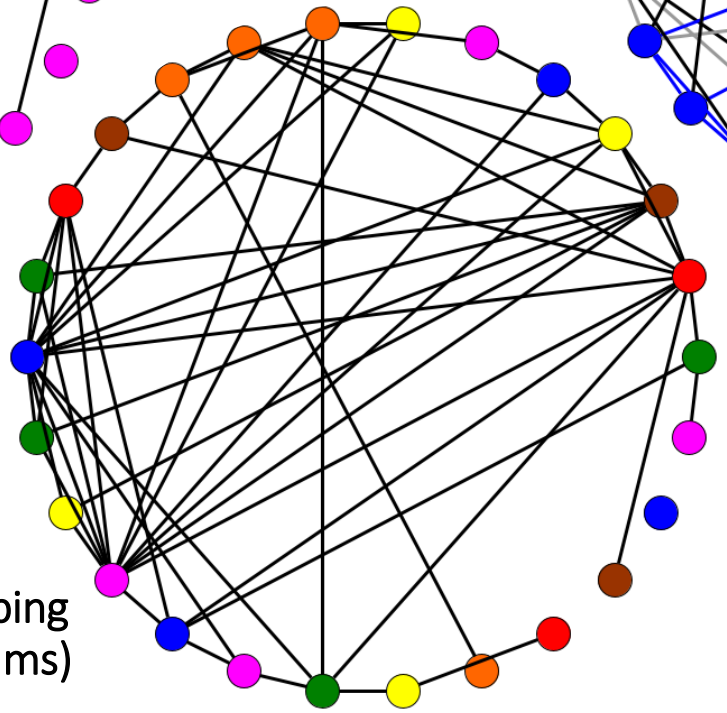
# Student Perception


- "One of the best teams of my IME [Industrial and Manufacturing Engineering] experience." [Class A]
- "This group is one of the most efficient and hardworking groups I have ever been a part of in Cal Poly [California Polytechnic State University]. Everyone was attentive and supportive to everyone's ideas and everyone contributed an equal amount. No one was left with an unequal workload, which is a common thing that happens in group projects. Overall, I am so pleased to end this quarter with two new friends and peers in IE [Industrial Engineering]." [Class B]
- "It was a nice experience to work with others in my major that I have never gotten the chance to work with before, even as a 4th Year Industrial Engineering major (I thought I knew everyone in my year!). I applaud for having that experience."[Class B]
- "Really quite liked this group; for a bunch of people that did not know each other, and in the case of XXX [name removed], came from rather different places, we all got along well and had a surprisingly enjoyable time considering how messy our simulation model was." [Class A]
- "We overall did not work well as a group." [Class A]
- "I truly feel that everyone did their fair share of the work. We had many zoom meetings where we all collaborated and worked together. While I was initially sad that the groups were assigned, it ended up working out really well for our team. We worked very well together and I was glad to meet some new classmates." [Class E]
- "I really liked getting to work with new people!" [Class E]
- "I made three great friends throughout this project, thank you for a great quarter professor!" [Class J]

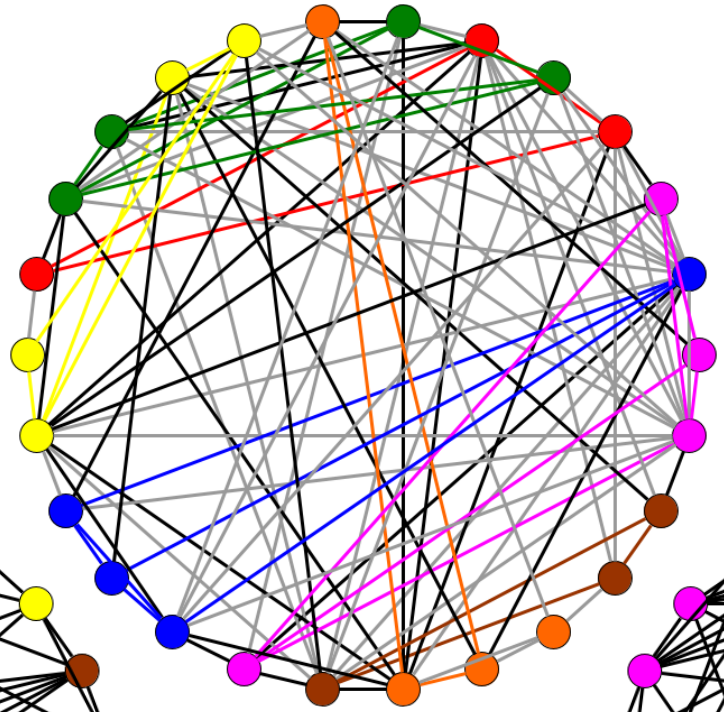
# **Example:** Operations Research II (J, 26 Students, Virtual)



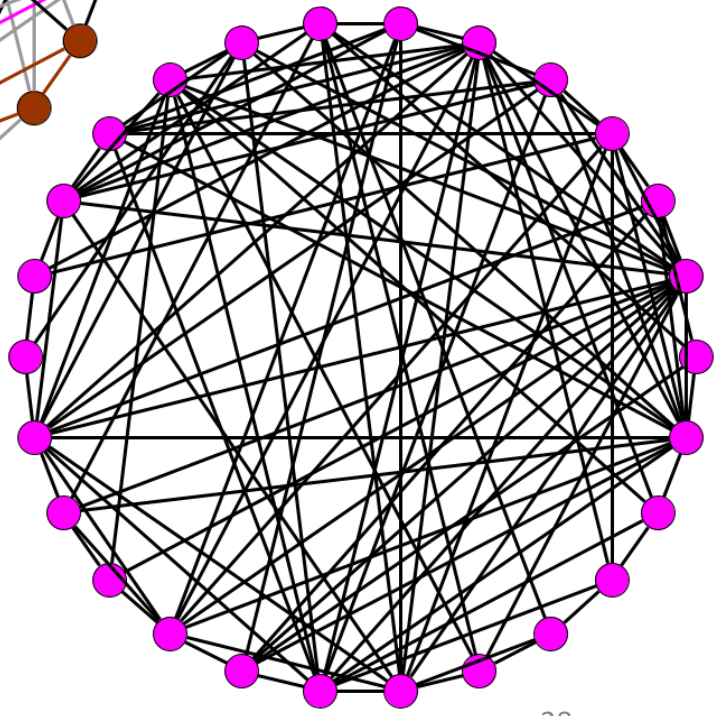
Initial
(57 Ties)



Grouping
(7 Teams)



Post-Project
(108 Ties)



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# Conclusion

- New Social Network Analysis & Optimization-based team model
- Case study with 10 classes in Industrial Engineering
- Comparison of grouping potentials
- Empirical impact analysis

Original - OR Modeling/Case Study | Published: 07 July 2023

Expanding students' social networks via optimized team assignments

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*Annals of Operations Research* (2023) | Cite this article

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1. "Easy" to apply as spreadsheet-based
2. Significant networking potential
3. Especially effective in virtual classrooms
4. Students like it

# Question:

**Any other ideas for how to positively influence the class social network?**

**Why not through a class seating plan?**

# Analytics for Classroom Social Networks

## Outline:

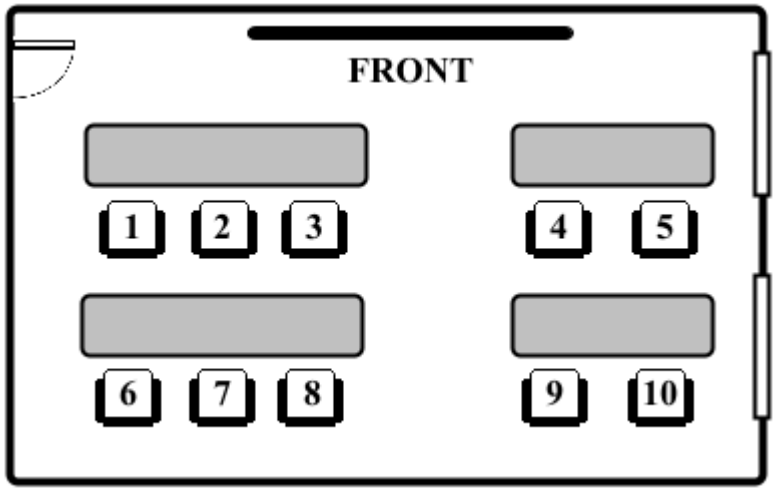
**A. Project Teams**

1. Motivation & Idea
2. Class Social Network
3. Optimization Model
4. Results & Analysis
5. Conclusion

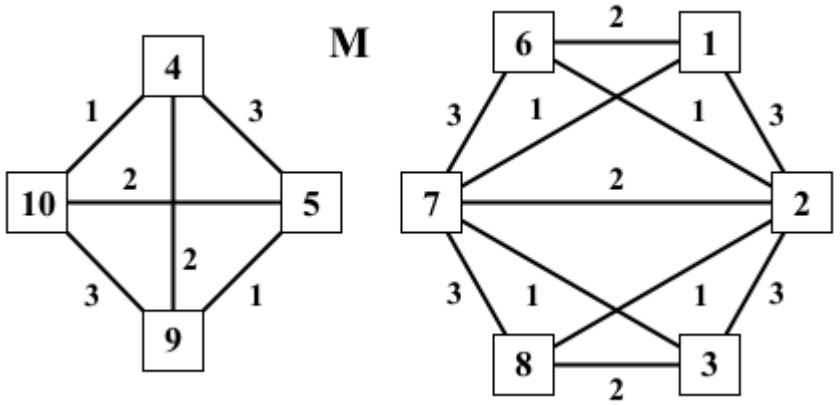
**B. Seating Arrangements**

**C. Rotational Grouping**

# Classroom Network & Tie Potentials




**Physical classroom with numbered seats**




**Abstract classroom network**

→ **Every node represents a seat**

→ **Edges represent a symmetric neighborhood relation**

→ **Edge weights represent the potentials for new ties**

# The Social Seating Assignment Problem

- Let N=(V,E) be the undirected student social network.
- Let M=(W,F) be the undirected weighted classroom network.
- Every edge e in F is associated with a tie potential p(e)>0.

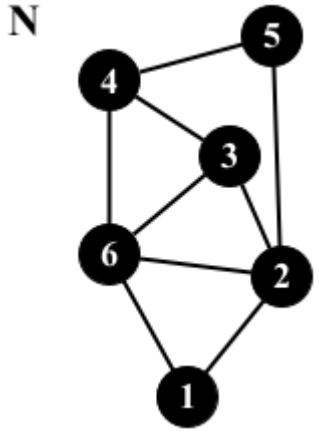
A seating assignment (SA) assigns each student in V to exactly one seat in W; at most one student to each seat.

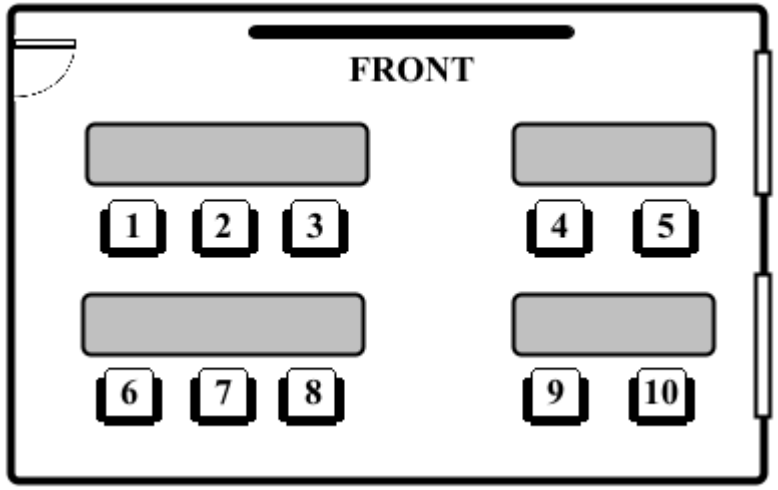
The overall tie potential (OTP) of a SA is the sum of all tie potentials in F between two seats with non-connected students assigned.

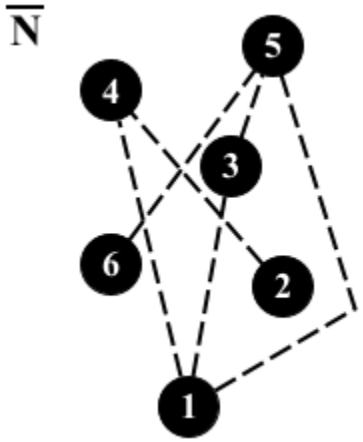
The Social Seating Assignment Problem* (SSAP) is to find a SA that maximizes the OTP.

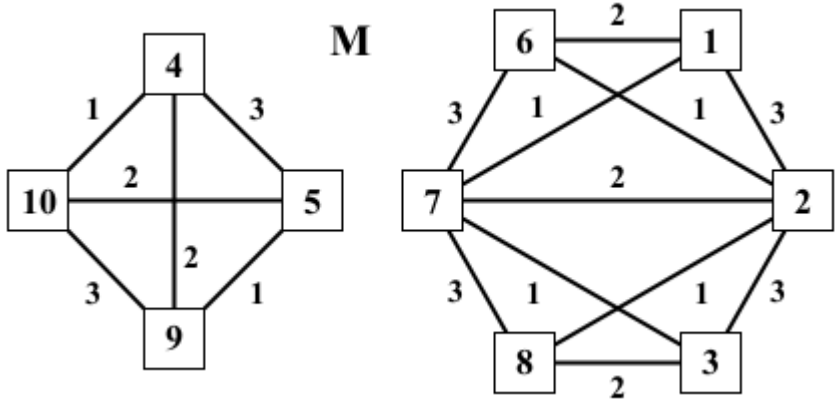
*$\boldsymbol{NP}$-hard

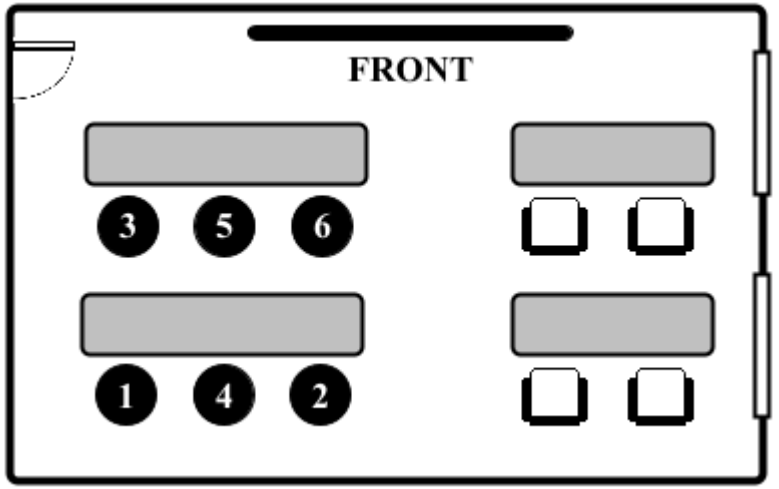
# Example Class: Optimal Assignment



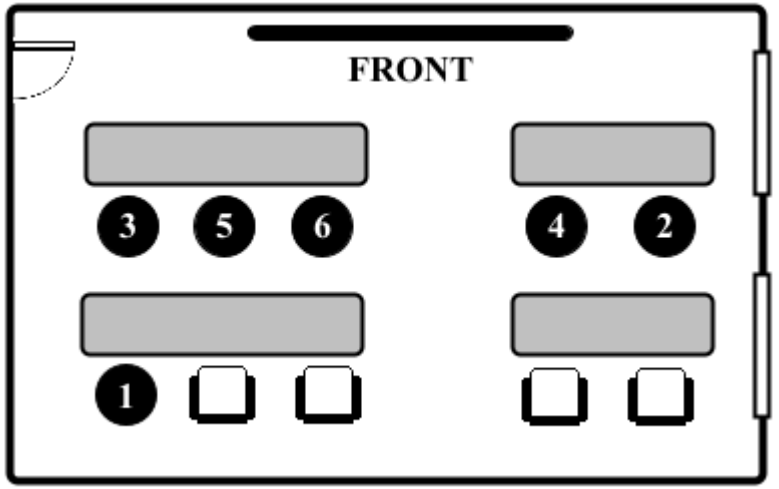




**Optimal Assignment (obj=22)**




**Optimal Assignment with Seat Preferences (1-5) (obj=12)**

# Practical Model Extensions

- Seat Pre-Assignment
- Zone Pre-Assignment
- Neighbor Pre-Assignment
- Neighbor Aversion
- Student Isolation
- Spatial Preferences
- Densities
- . . .

→ Integration of student special needs

→ Integration of instructor preferences

# Integer Programming Formulation (F)

$$x_{i,j} = \begin{cases} 0 & \text{student } i \text{ is not assigned to t seat } j \\ 1 & \text{student } i \text{ is assigned to t seat } j \end{cases}$$

$$z_{j,j'} = \begin{cases} 0 & \text{seats } j \text{ and } j' \text{ are not assigned to two students that do not know each other} \\ 1 & \text{seats } j \text{ and } j' \text{ are assigned to two students that do not know each other} \end{cases}$$

$$(F) \quad Maximize \quad \sum_{\{j,j'\} \in F} p_{j,j'} \cdot z_{j,j'}$$

***Weighted Tie Potentials Objective***

$$Subject\ to \quad \sum_{j \in W} x_{i,j} = 1 \qquad \forall i \in V$$

***Unique Student Assignment***

$$\sum_{i \in V} x_{i,j} \leq 1 \qquad \forall j \in W$$

***Unique Seat Assignment***

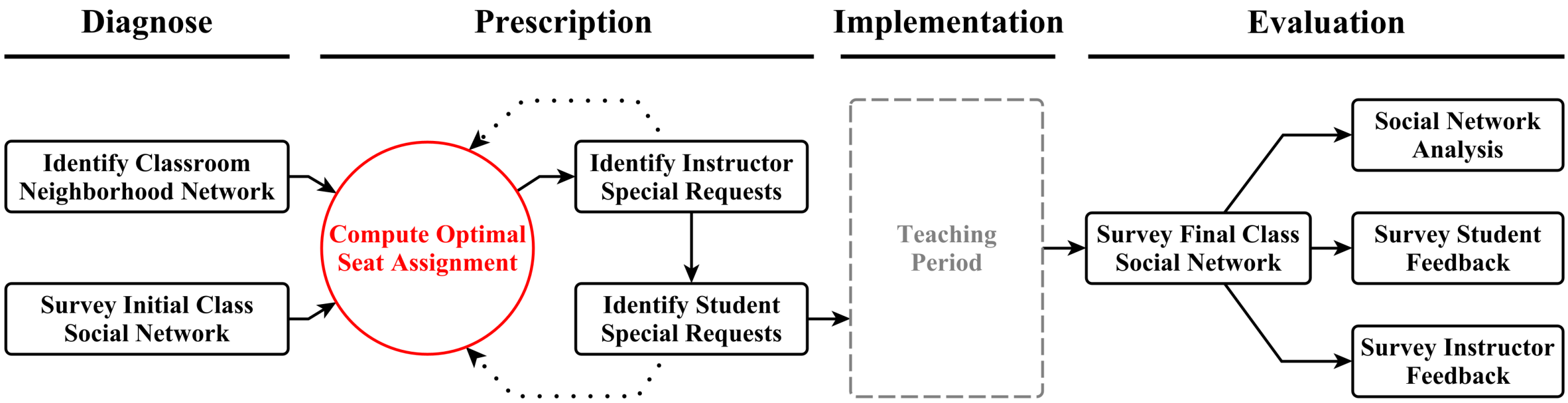
$$z_{j,j'} + x_{i,j} + x_{i',j'} \leq 2, \quad z_{j,j'} + x_{i,j'} + x_{i',j} \leq 2 \qquad \forall \{i,i'\} \in E, \{j,j'\} \in F$$

***Variable Linking (Non-empty seats)***

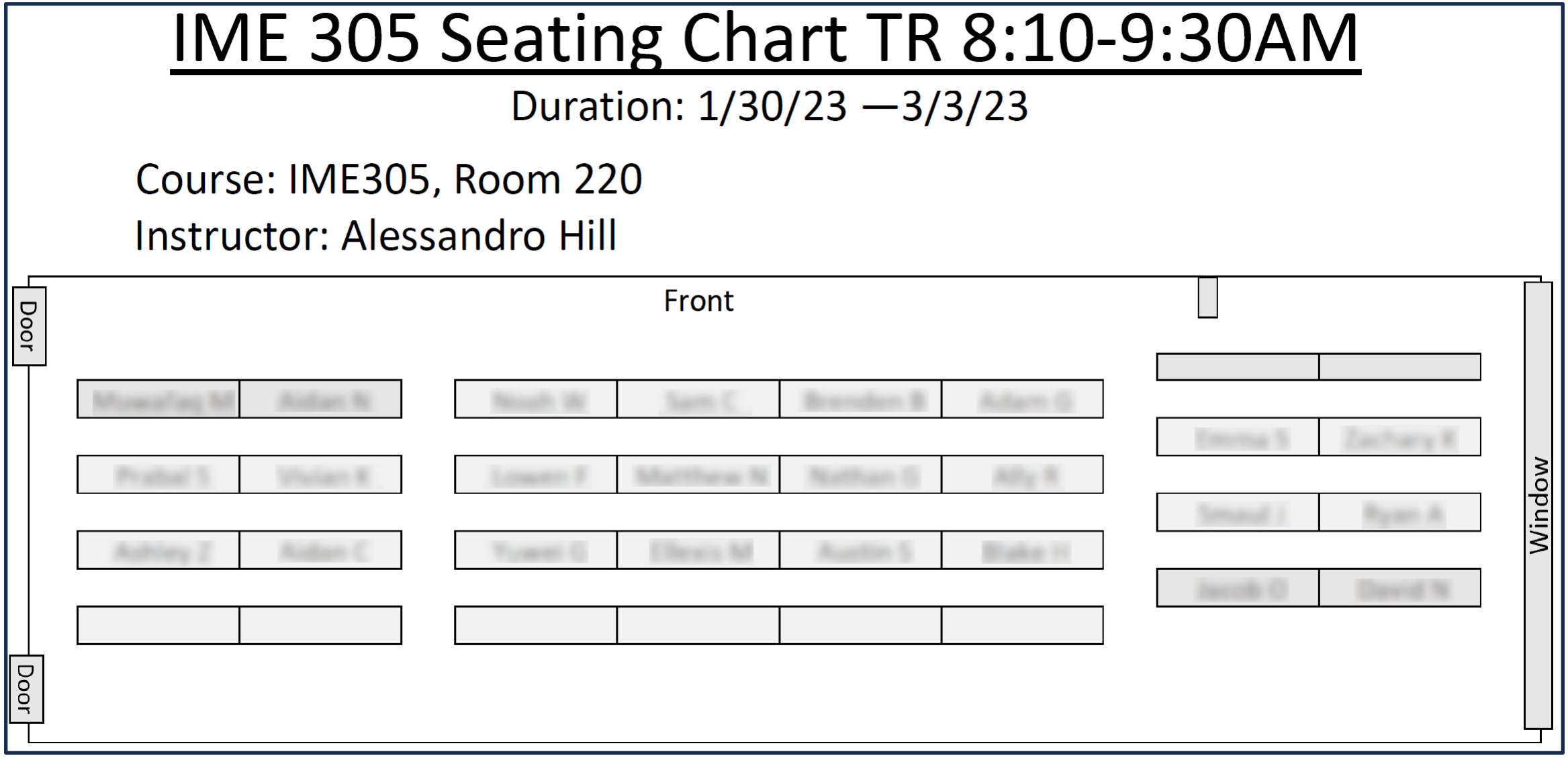
$$z_{j,j'} \leq \frac{1}{2} \sum_{i \in V} (x_{i,j} + x_{i,j'}) \qquad \forall \{j,j'\} \in F$$

***Variable Linking (Empty seat)***

# New Approach: Process



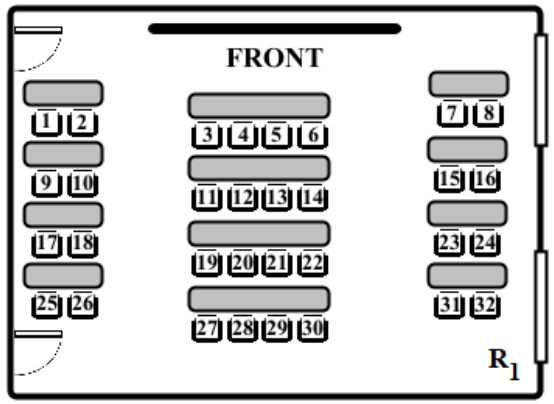
# Seating Plan Example

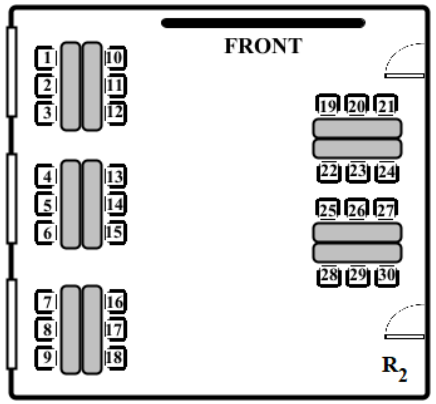


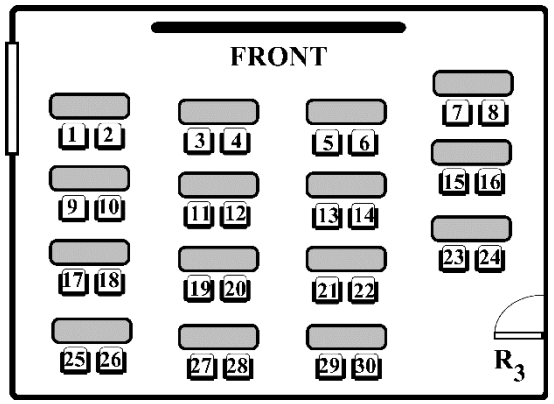
# Survey Data

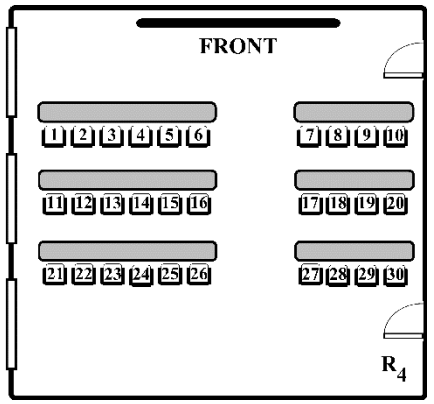
| Course | | | | SN Survey | | Classroom | | | | | Method |
|---|---|---|---|---|---|---|---|---|---|---|---|
| # | | Name | $\|V\|$ | $RR_0$ | $RR_1$ | # | $\|W\|$ | $\|F_H\|$ | $\|F_V\|$ | $\|F_D\|$ | |
| A | IME 301 | Operations Research I | 27 | 96.2 | 92.3 | $R_1$ | 32 | 20 | 24 | 30 | OPT |
| B | IME 305 | Operations Research II | 24 | 95.8 | 95.8 | $R_1$ | 32 | 20 | 24 | 30 | OPT |
| C | IME 420 | Simulation | 21 | 100.0 | 90.5 | $R_2$ | 30 | 20 | 15 | 20 | OPT |
| All | 3 | | 72 | 97.3 | 92.9 | 2 | | | | | |
| D | IME 156 | Basic Electronics Manufacturing | 21 | 100.0 | 66.7 | $R_5$ | 180 | 488 | 0 | 320 | SELF |
| E | IME 212 | Introduction to Enterprise Analytics | 28 | 92.9 | 85.7 | $R_3$ | 30 | 15 | 22 | 24 | SELF |
| F | IME 410 | Production Planning & Control Systems | 23 | 91.3 | 69.6 | $R_1$ | 32 | 20 | 24 | 30 | SELF |
| G | IME 417 | Supply Chain & Logistics Management | 30 | 76.7 | 60.0 | $R_2$ | 30 | 20 | 15 | 20 | SELF |
| H | IME 443 | Facilities Planning & Design | 18 | 94.4 | 88.9 | $R_3$ | 30 | 15 | 22 | 24 | SELF |
| I | IME 223 | Process Improvement Fundamentals | 31 | 93.5 | 58.1 | $R_1$ | 32 | 20 | 24 | 30 | SELF |
| J | IME 372 | Applications of Enterprise Analytics | 23 | 87.0 | 69.6 | $R_4$ | 30 | 24 | 20 | 32 | SELF |
| All | 7 | | 173 | 90.8 | 71.2 | 4 | | | | | |
| All | 10 | | 245 | 92.8 | 77.7 | 5 | | | | | |

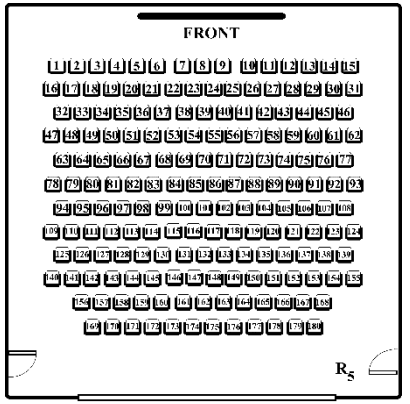
# Example Classrooms

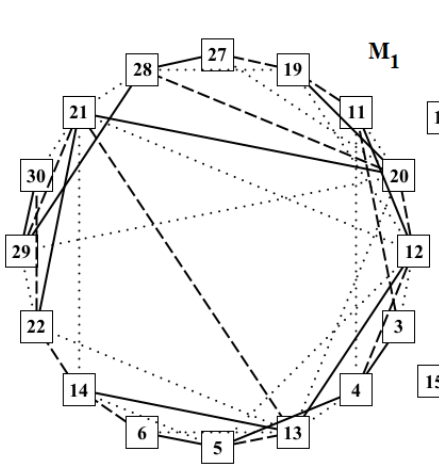


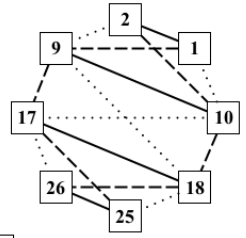



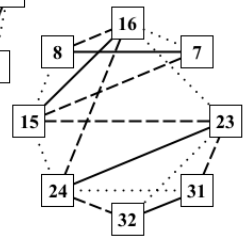



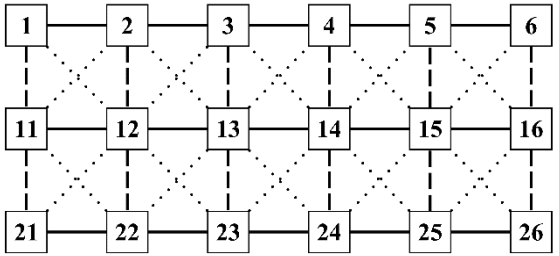



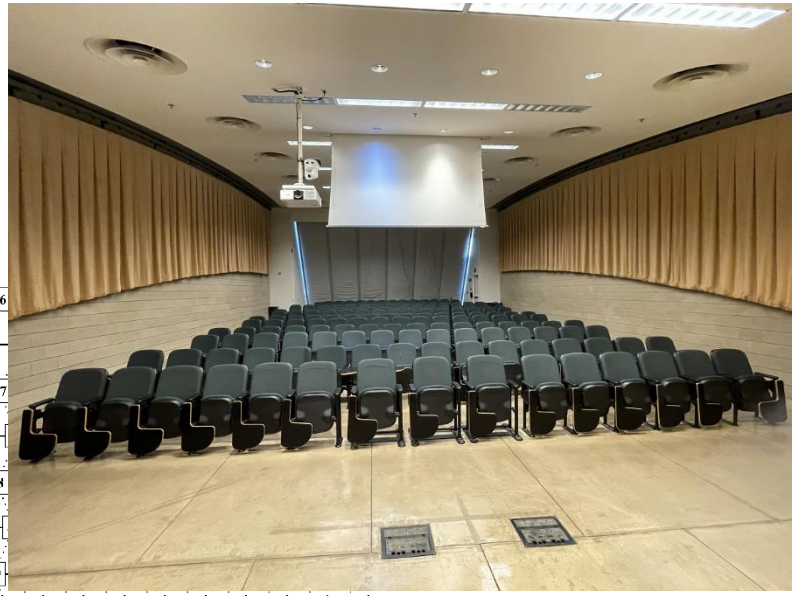



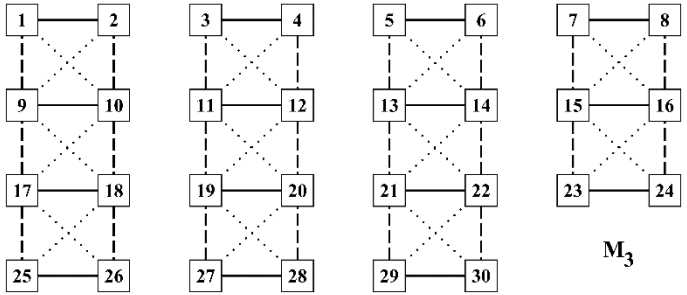



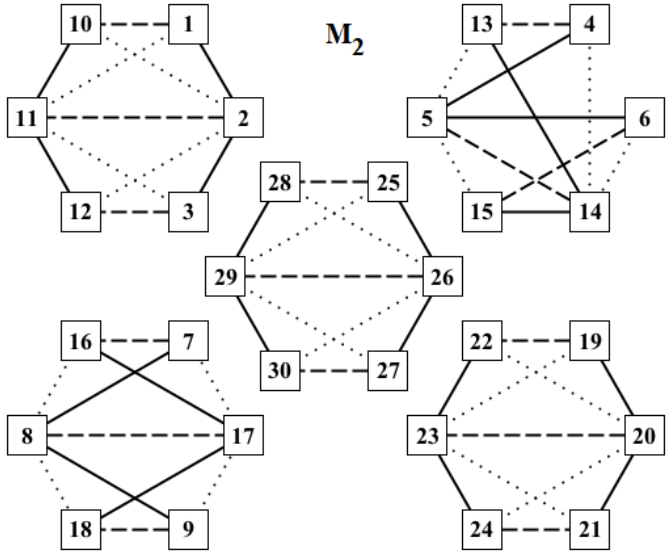



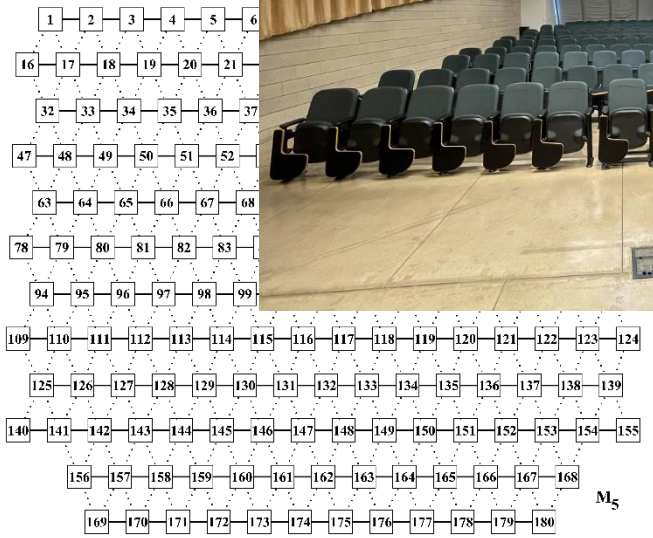




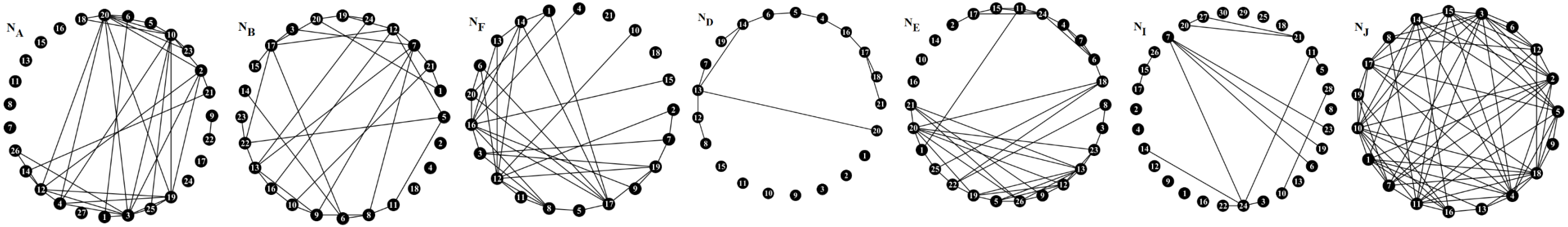


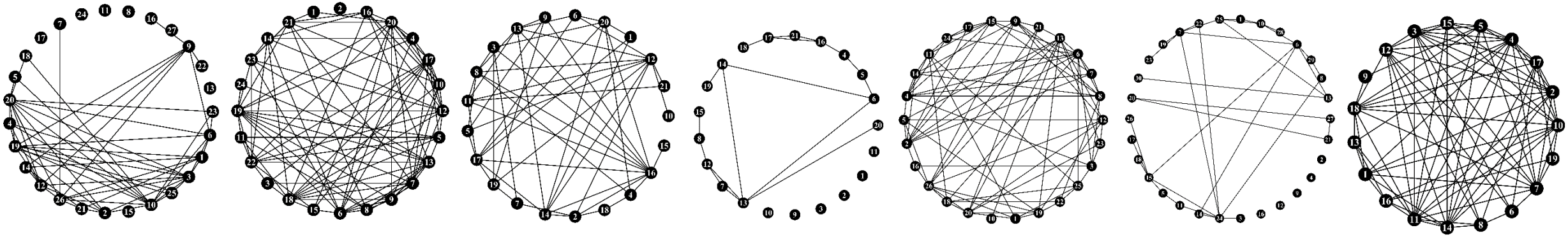



# Example Class Social Networks

BEFORE




AFTER



# Instructor Perception

POSITIVE

| # | Comment |
|---|---|
| 1 | "Immediately introduced each other and collaborated. Good to see more diverse communication/collaboration" |
| 2 | "Students met and socialized with some students they had never spoken with before." |
| 3 | "There was a lot of interaction in the group assignments. I can't be sure that it was more than not having the pre-arranged assignment, but it was definitely noticeable." |

CRITICAL

| # | Comment |
|---|---|
| 1 | "No communication for at least one table. No collaboration when non-shows caused isolated students" |
| 2 | "In classroom 240 some students needed to move to the center tables to see the screen better" |
| 3 | "Only one student - there was an external reason for the student desiring to sit separately, nothing to do with an individual in the class." |

# Student Perception

POSITIVE

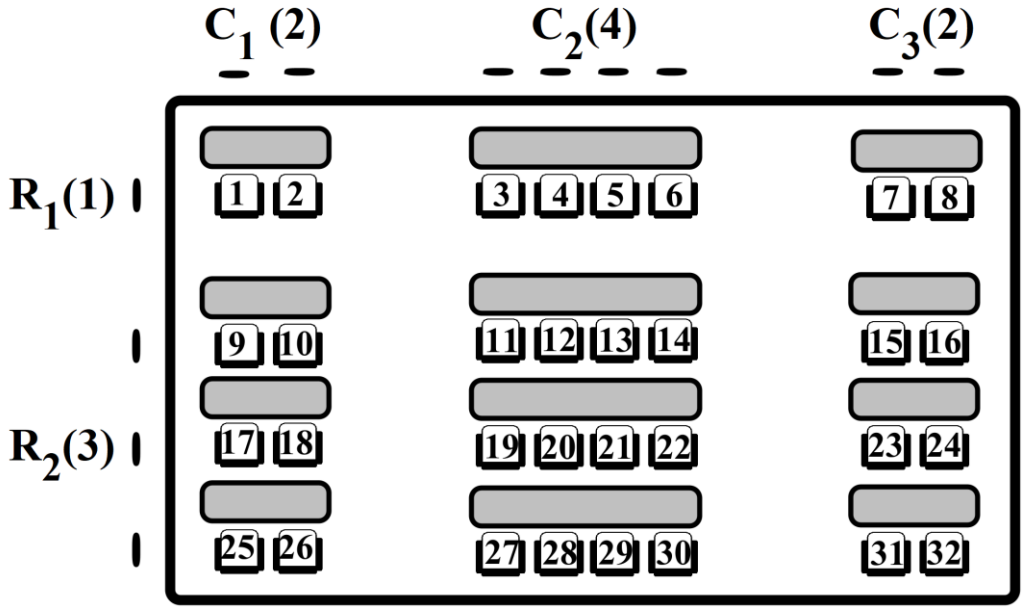
| # | Comment |
|---|---|
| 1 | "I knew my neighbors a little before, but I'm definitely more comfortable with them after this!" |
| 2 | "There weren't any glaringly obvious issues with it and it was fairly easy to follow." |
| 3 | "I sat next to my TA for 312 at the time so it was really cool for me to talk to him and get to know him more. Every time I see him we end up talking for a bit so that's really cool. I don't think that would've happened and I probably would've sat with people I already know if the seating chart didn't exist." |
| 4 | "I hadn't met them before and still talk to them now." |
| 5 | "It was nice being at the front of the class." |
| 6 | "I think that it was really good idea that could potentially have many positive impacts." |
| 7 | "I enjoyed being "forced" to meet other people in my class as it brought me closer to other IME students." |
| 8 | "Was able to interact with people I have not talked to before." |
| 9 | "It was nice getting to know someone from my department and help each other out through the class! This would encourage students to interact out of your circle that you start to form as an upperclassmen." |
| 10 | "It was a good experience to interact with classmates I have not interacted." |
| 11 | "The seating assignment gave me a chance to talk to one of my neighbors that I had other classes with before but never really interacted with." |
| 12 | "Loved interacting with new students and building new friendships. It positively impacted school since interacting with these students helped me understand material better." |
| 13 | "I met more people that I didn't know." |
| 14 | "It was a change of pace from hanging with the same people." |

CRITICAL

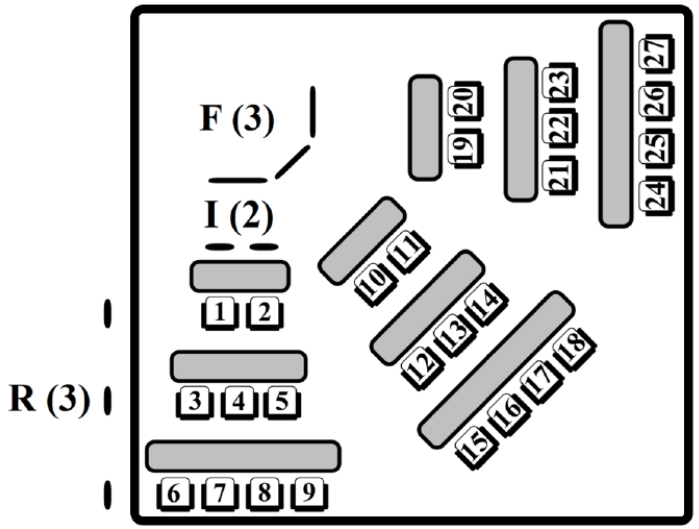
| # | Comment |
|---|---|
| 1 | "My group was a group of 3, while the tables were organized to fit 6 each. Dispersing the empty seats among the class instead of having one half-empty table would help. |
| 2 | "I prefer to sit in the back of the classroom as it makes me nervous to have people behind me in a work situation. I found it incredibly difficult to focus during lecture and discussions when this was not the case. As well, I recently transferred into the IME dept so I was not sat next to the few people I had connected with and it was difficult to make connections in a 400 level lecture course." |
| 3 | "I feel like some people who typically sit at the front to have a good view/be more interactive with the professor were forced to sit somewhere in the back and that caused some issues. Other than that nothing really." |
| 4 | "Had to move seats because I have bad vision and was placed in the very back row." |
| 5 | "I did not enjoy being seated in the back of the class as I tend to not learn as much when I am not sitting in the front of the class." |
| 6 | "I prefer to be seated closer to the board so I can see without any large obstruction/distractions!" |
| 7 | "I sit with people I know I can trust and who are proven to be beneficial to my learning. I was friendly but the person I sat with (no one else at our two person table) hardly ever spoke to me. He was clearly behind and struggling in the class but refused to ask me questions/help himself. I would have been happy to help once in a while is it bc we were strangers, or I am a woman, or he just had too much or too little ego idk. So obviously since he was so far behind he couldn't help me if I had a question and it was def not a mutually beneficial arrangement. There is a reason why I sit by people I know and trust." |
| 8 | "I think the seating assignment might be less worthwhile if it's a class that doesn't lend itself well to discussions and/or group work." |
| 9 | "I did not get the chance to talk to the people that were assigned to nearby seats to me so it was overall a neutral experience." |
| 10 | "I am sure not everyone had the same experience, but my seatmates were very favorable." |
| 11 | "While I met more people most of the interactions were surface level." |
| 12 | "Some of the seats in the the room are very hard to learn in because they face away from the lecture. I would not have chosen that seat because of that reason. I did not learn new names either because I was too busy learning in lecture and not talking with my neighbors beyond surface level." |
| 13 | "I got seated to the side of the room with only one classmate. I did not know him or interact with him at all throughout the quarter. I sat with people I knew before the assigned seating." |
| 14 | "I think the seating assignments results really just depends on the dynamic you have with the other person. For instance, I didn't feel comfortable with my partner because first off he didn't sit in the right seat. He sat on my seat even though he knew which one was his. Also he would always just leave his jacket laid out on the table making it uncomfortable. But if I was seated to someone who was friendly enough to make small talk, the experience would have been positive." |

# Scaling Up – Experiments

- Generated **320 random problem instances**
  → Real SNs and denser versions (24-936 edges)
  → “Rectangular” and “circular” classrooms
  → 10-200 Students
  → 16-365 Seats
- Developed three **stronger IP formulations**
- Tested a **quadratic formulation**
- 7 constructive **heuristic** strategies
  + two **local search** neighborhoods
- Python and Gurobi 10.0.3




Instance Parameters: R=[1,3] C=[2,4,2]




Instance Parameters: [R,F,I]=[3,3,2]

# Example Network Formats

**Social Network (Edge Format)**

SN-1-s1-n10-m6.txt

```
10
6
1 9
1 3
9 3
8 6
6 5
10 4
```

**Social Network (Neighbor Format)**

SN-1-s1-n10-m6_B.txt

```
10
1 3 9 8
2
3 9
4 10 1
5 6
6 5
7
8 6
9 3
10 4 1
```

**Classroom Network**

Room-1-R-2-2-C-2-2.txt

```
16
24
1 2 3
1 3 2
1 4 1
2 3 1
2 4 2
3 4 3
5 6 3
5 7 2
5 8 1
6 7 1
6 8 2
7 8 3
9 10 3
9 11 2
9 12 1
10 11 1
10 12 2
11 12 3
13 14 3
13 15 2
13 16 1
14 15 1
14 16 2
15 16 3
```

# Example Assignment Format

**Seating assignment (SA)**

S_SN-1_Room-1_obj11.0.txt

```
10
144

1 140
2 134
3 142
4 18
5 130
6 133
7 139
8 19
9 50
10 9
```

# Example Optimization Model

**Python script using the Gurobi MIP solver (https://www.gurobi.com/)**

```
        #Objective
        m.setObjective(gu.quicksum(w['weight']*VarsZ[j1,j2] for j1, j2, w in M.edges(data=True)), gu.GRB.MAXIMIZE)
        m.update()

        #Constraints: Unique Student-to-seat Assignment (1)
        m.addConstrs(gu.quicksum(VarsX[i,j] for j in M.nodes) == 1 for i in N.nodes)
        m.update()

        #Constraints: At most one seat-to-student Assignment (2)
        m.addConstrs(gu.quicksum(VarsX[i,j] for i in N.nodes) <= 1 for j in M.nodes)
        m.update()

        #Constraints: Linking (3)
        if Formulation == "F1" or Formulation == "F2" or Formulation == "F3":
            print( "Constr for Assigned Neighbors (X-Z)...")
            #N_C = nx.complement(N)
            m.addConstrs(VarsZ[z[0],z[1]] <= 2 - VarsX[x[0],z[0]] - VarsX[x[0],z[1]] - VarsX[x[1],z[0]] - VarsX[x[1],z[1]] for x in N.edges for z in M.edges)
            m.update()
        if Formulation == "F0":
            print( "Constr for Assigned Neighbors (X-Z, weak)...")
            #N_C = nx.complement(N)
            m.addConstrs(VarsZ[z[0],z[1]] <= 2 - VarsX[x[0],z[0]] - VarsX[x[1],z[1]] for x in N.edges for z in M.edges)
            m.update()
            m.addConstrs(VarsZ[z[0],z[1]] <= 2 - VarsX[x[0],z[1]] - VarsX[x[1],z[0]] for x in N.edges for z in M.edges)
            m.update()

        #Constraints: No tie potentials in the case of empty seats (4)
        if Formulation == "F1" or Formulation == "F0":
            print( "Constr No Empty Seat Pot (X-Z)...")
            m.addConstrs(VarsZ[z[0],z[1]] <= 0.5 * gu.quicksum(VarsX[i,z[0]]+VarsX[i,z[1]] for i in N.nodes) for z in M.edges)
            m.update()

        if Formulation == "F2":
            print( "Constr No Empty Seat Pot (strong 1)...")
            m.addConstrs(VarsZ[z[0],z[1]] <= gu.quicksum(VarsX[i,z[0]] for i in N.nodes) for z in M.edges)
            m.update()
            m.addConstrs(VarsZ[z[0],z[1]] <= gu.quicksum(VarsX[i,z[1]] for i in N.nodes) for z in M.edges)
            m.update()

        if Formulation == "F3":
            print( "Constr No Empty Seat Pot (strong 2)...")
            m.addConstrs(gu.quicksum(VarsZ[min(_e[0],_e[1]),max(_e[0],_e[1])] for _e in M.edges(j)) <= M.degree(j) * gu.quicksum(VarsX[i,j] for i in N.nodes) for j in M.nodes)
            m.update()

        #print(M.edges)
        #for j in M.nodes:
        #    print("nM"+str(j)+": ")
        #    print(M.edges(j))

        #Optimize
        #m.Params.Threads = 1
        m.setParam("Heuristics", 0.00)
        #m.write(PathExport+FileN[0:4]+'_'+FileM[0:6]+".lp")
        m.setParam('OutputFlag', 0)
        m.setParam("TimeLimit",timeLimit)
        m.setParam("NodeLimit",nodeLimit)
        m.optimize()
```