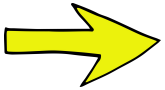
The Feedback Loop in Forming and Supporting Student Teams

Dr. Bowen Hui
Computer Science
University of British Columbia

Technology-Enhanced Personalized Learning



Technology to maximize learning outcomes for ***individuals***

Technology to maximize learning outcomes in ***teams***

Teamable Analytics: Team Formation Software

- Supporting teamwork in large classes
  - Developed general-purpose inclusive team formation algorithm
  - Benchmarked algorithms and introduced diversity metrics
  - Built Canvas-integrated web tool to assist instructors
  - Developing visual analytics to detect anomaly behavior
  - Analyzing teamwork behavior

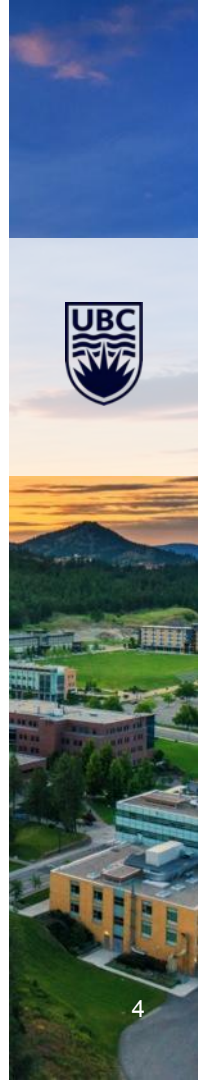
- Our open-source platform ***Teamable Analytics***: **https://teamableanalytics.ok.ubc.ca/homepage/**
  - Used in 39 interdisciplinary classes at UBC and impacting 5,000 students

Why Teams?

- Collaborative problem solving leads to better outcomes
  - Increases productivity
  - Encourages personal growth
  - Promotes innovation
  - Builds stronger relationships

- Attention on teamwork in educational and workplace settings
  - A core 21st Century skill

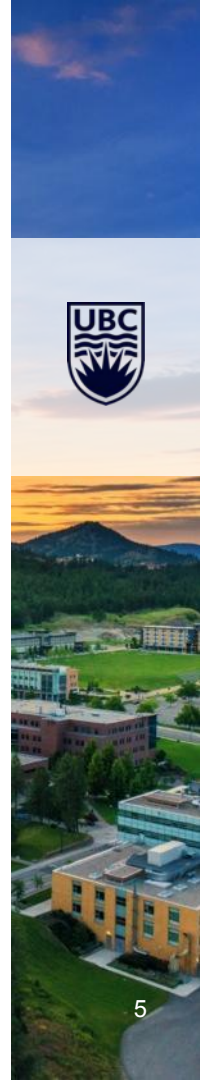
- ***Team formation task:***
  - Assign all students into non-overlapping groups
  - A.k.a. Group formation, team assembly
  - NP-hard problem [Lappas et al., 2009; Eftekhar et al., 2015]



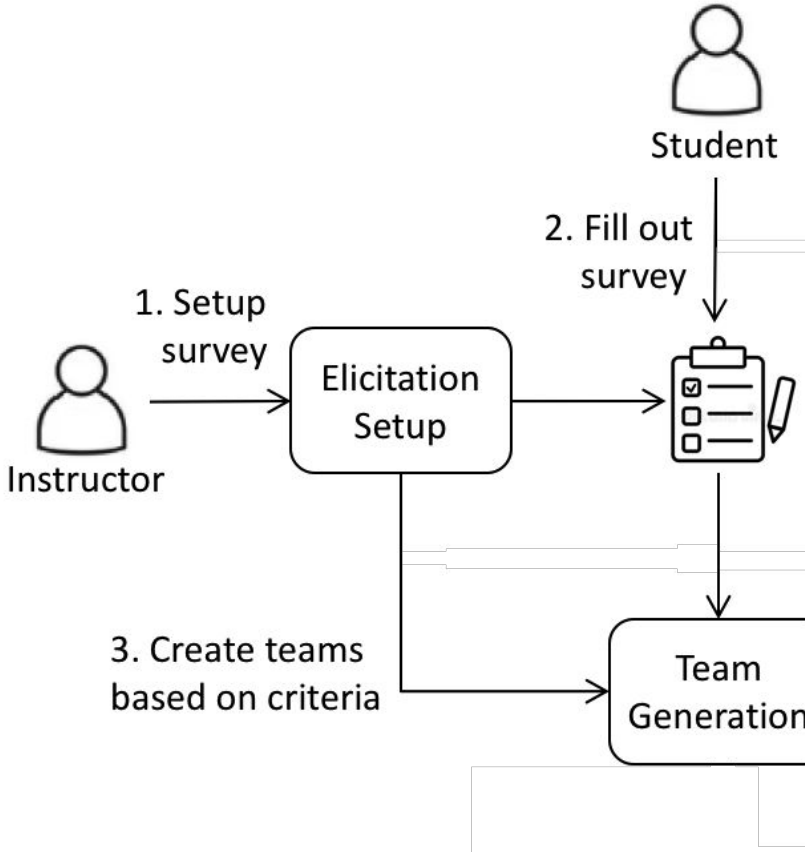
Current Approaches to Forming Teams

- Random → Works with no preferences, skills, or needs
- Self-assembled → Unbalanced
- Manually + strategically → Only works in small classes

- External tool (40+ students):
  - **Grumbler** [Sparrow 2011]
    - Spreadsheet interface, no peer evals
  - **CATME** [Layton et al. 2010; Ohland et al. 2012]
    - Cost, complex UI, has self/peer eval, cannot modify teams
  - No integrated with LMS
  - Focus on diversifying (not clustering) students
  - No project-to-skills matching

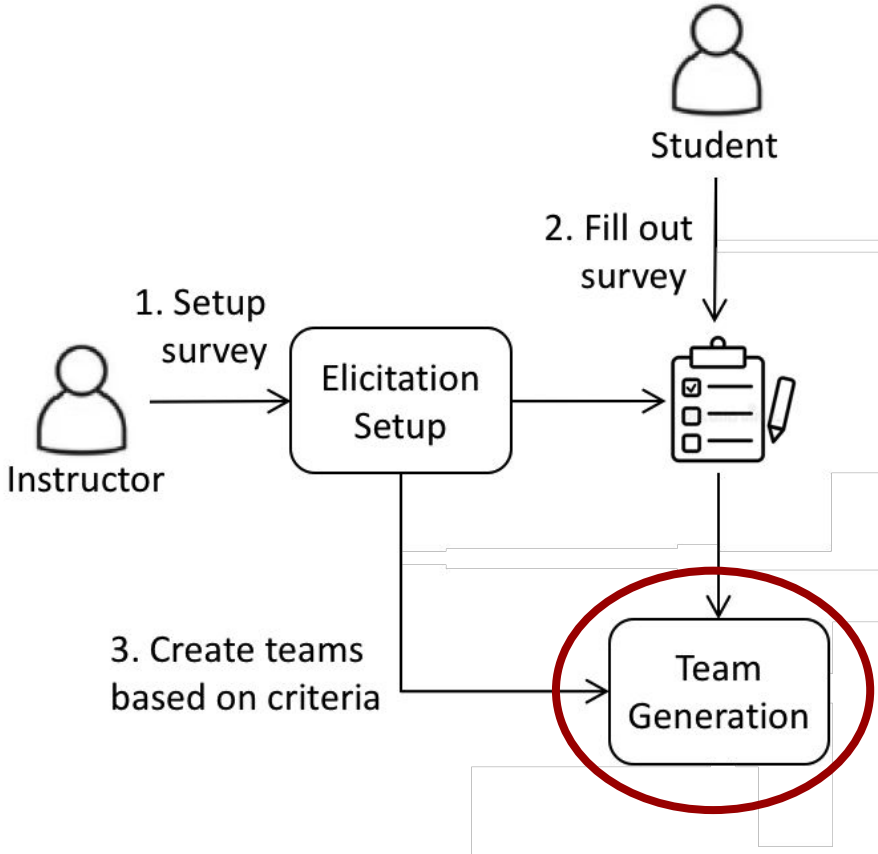


Team Formation Use Cases



Basic use case for forming teams strategically

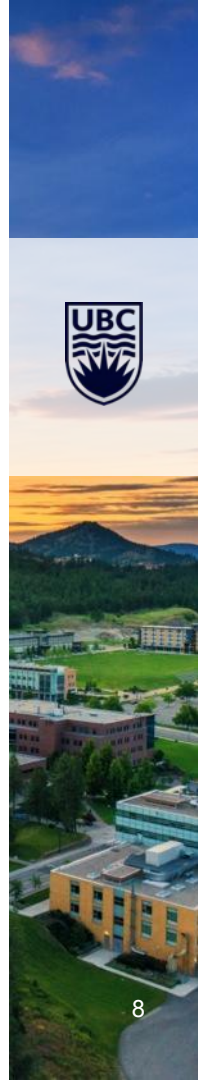
Team Formation Use Cases



- CSCL algorithms
- Various AI algorithms
- Algorithms from specific disciplines

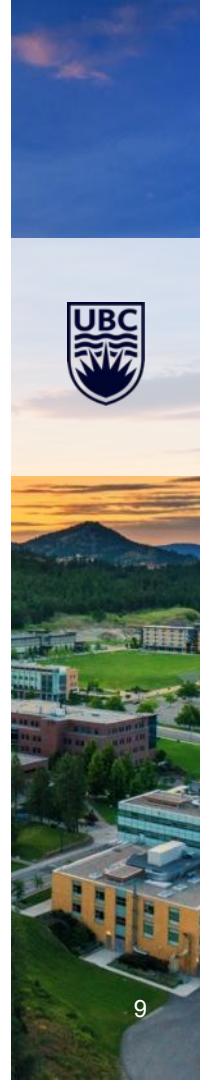
Related Work:
Computer Supported Collaborative Learning (CSCL)

- 5 literature reviews between 2014-2019
- Educators consider a variety of learner characteristics
  - Diversifying on a learner characteristic is most common
  - Use a mix of heterogeneous and homogeneous criteria



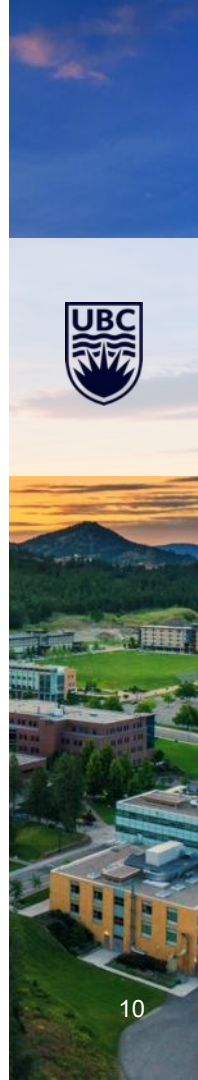
Related Work:
Computer Supported Collaborative Learning (CSCL)

- 5 literature reviews between 2014-2019
- Educators consider a variety of learner characteristics
  - Diversifying on a learner characteristic is most common
  - Use a mix of heterogeneous and homogeneous criteria
- Algorithms adopt various AI/ML approaches
  - Some are not implemented
  - Algorithms not always evaluated
  - No comparison of algorithms on relative effectiveness
  - Not open-sourced or publicly available



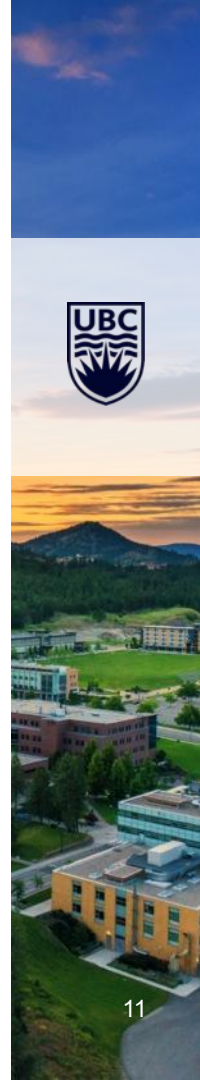
Related Work:
Computer Supported Collaborative Learning (CSCL)

- 5 literature reviews between 2014-2019
- Educators consider a variety of learner characteristics
  - Diversifying on a learner characteristic is most common
  - Use a mix of heterogeneous and homogeneous criteria
- Algorithms adopt various AI/ML approaches
  - Some are not implemented
  - Algorithms not always evaluated
  - No comparison of algorithms on relative effectiveness
  - Not open-sourced or publicly available
- Only 1 paper in 2017 used gender and language as criteria, but no metrics, no diagnosis, no consideration to **tokenism** [Amarasighe et al. 2017]



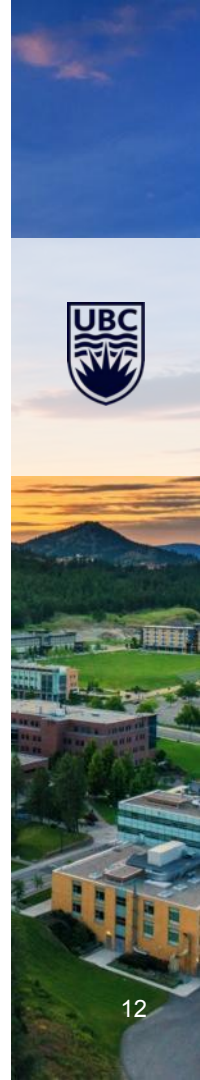
Related Work: AI Areas

- ***Group Activity Selection Problem (GASP)***
  - Assign individuals to groups based on preferences over groups and potential teammates [Igarashi et al., 2017]
  - Do not consider project-to-skills matching



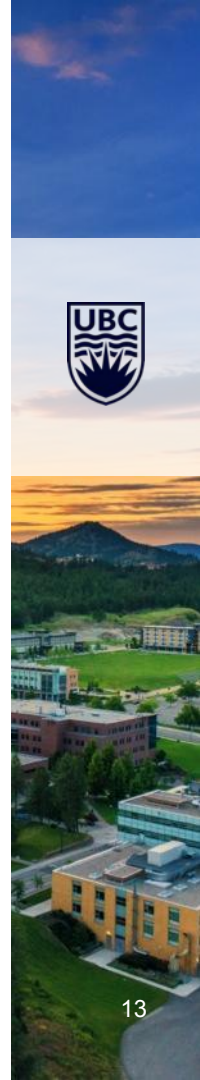
Related Work: AI Areas

- ***Group Activity Selection Problem (GASP)***
  - Assign individuals to groups based on preferences over groups and potential teammates [Igarashi et al., 2017]
  - Do not consider project-to-skills matching
- ***Team Formation Problem (TFP)***
  - Create one team to complete task by matching requirements while minimizing communication costs within team [Lappas et al., 2009]
  - **Multiple TFP** - limited to modeling each person with one skill [Gutiérrez et al., 2016]



Related Work: AI Areas

- ***Group Activity Selection Problem (GASP)***
  - Assign individuals to groups based on preferences over groups and potential teammates [Igarashi et al., 2017]
  - Do not consider project-to-skills matching
- ***Team Formation Problem (TFP)***
  - Create one team to complete task by matching requirements while minimizing communication costs within team [Lappas et al., 2009]
  - **Multiple TFP** - limited to modeling each person with one skill [Gutiérrez et al., 2016]
- ***Fair Division***
  - Assign resources to agents fairly via utility function [Aziz et al., 2017]
  - **Double Round Robin (DRR)** - create envy-free up-to-1 allocation [Aziz et al., 2022]
  - **Greedy Round Robin (GRR)** - next



Greedy Round Robin [CAI/LNCS 2020]

- Models students as resources
- Allocate students to projects weighted against social preferences and diversity constraints via utility function
  - Project requirements, project preferences, social preferences, diversity constraints

Greedy Round Robin [CAI/LNCS 2020]

- Models students as resources
- Allocate students to projects weighted against social preferences and diversity constraints via utility function
  - Project requirements, project preferences, social preferences, diversity constraints

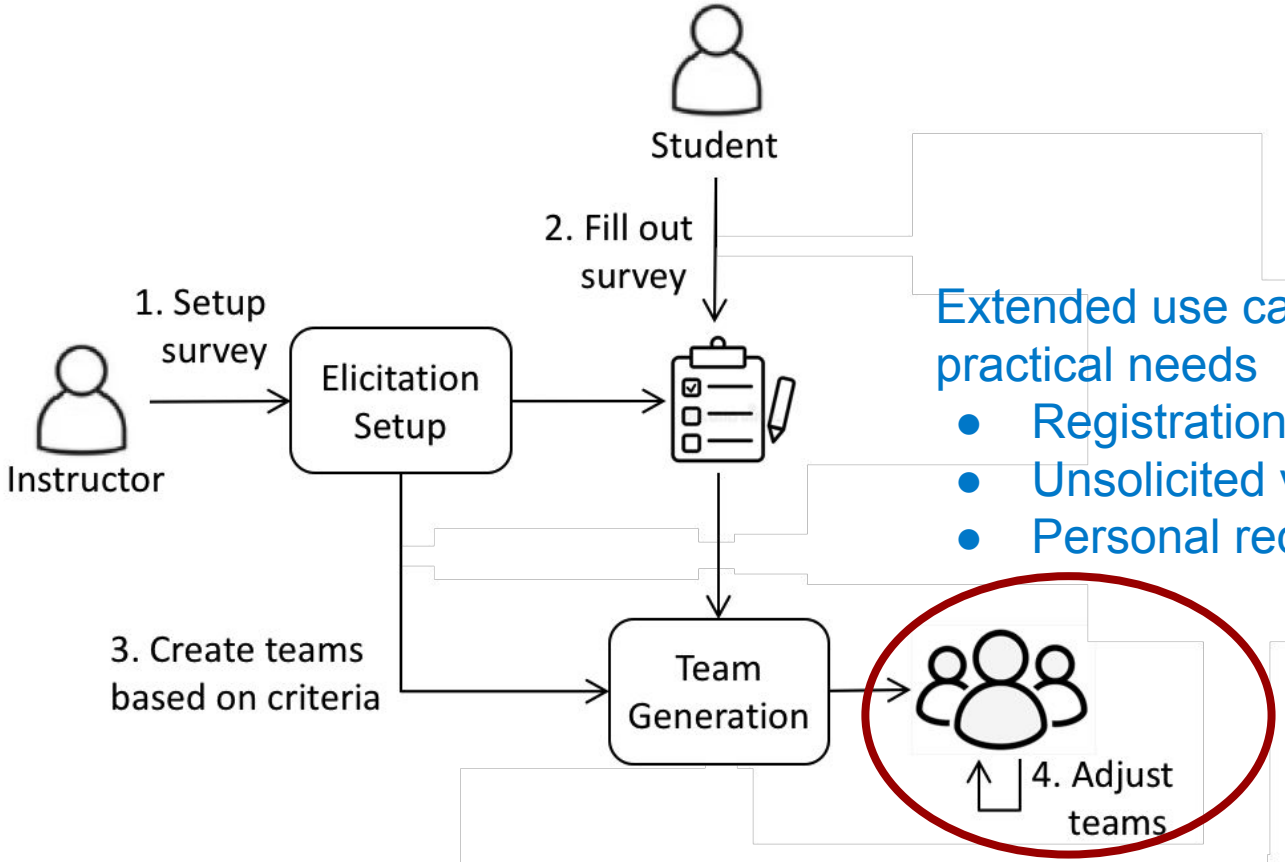
- Benchmarking results outperformed state-of-the-art algorithms
  - Metrics: speed, envy-freeness-up-to-1, activity cover
- Promising pilot study feedback 09/2019-04/2020
  - Class sizes between 41 and 161 students
  - Positive ***student satisfaction*** and ***activity coverage*** on projects

Greedy Round Robin [CAI/LNCS 2020]

- Models students as resources
- Allocate students to projects weighted against social preferences and diversity constraints via utility function
  - Project requirements, project preferences, social preferences, diversity constraints

- Benchmarking results outperformed state-of-the-art algorithms
  - Metrics: speed, envy-freeness-up-to-1, activity cover
- Promising pilot study feedback 09/2019-04/2020
  - Class sizes between 41 and 161 students
  - Positive ***student satisfaction*** and ***activity coverage*** on projects
- Lessons:
  - Instructors need to augment generated teams
  - Software needs user-friendly front-end
  - Doesn't cover all the specialized use cases

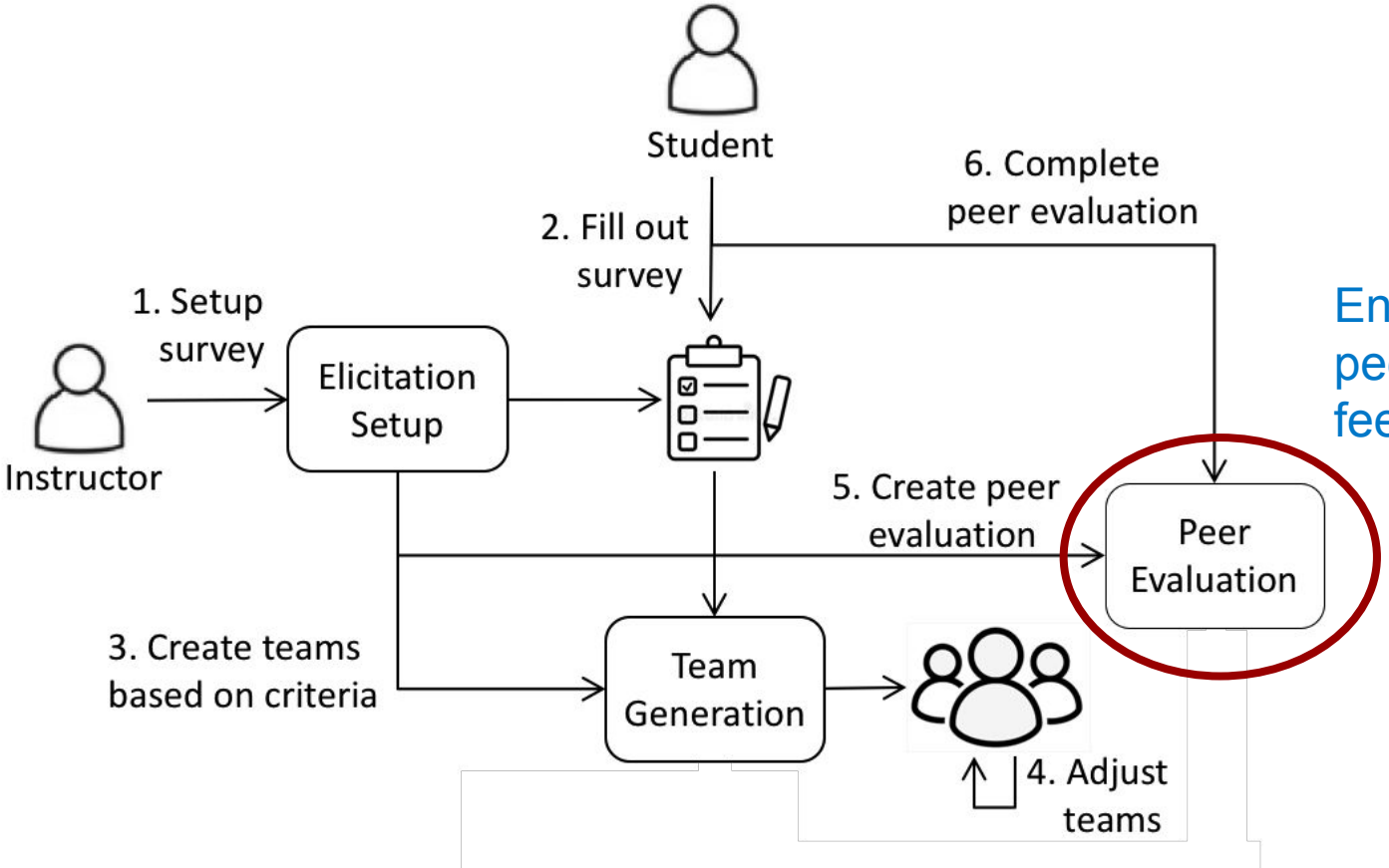
Team Formation Use Cases [CSEDU, 2022]



Extended use case due to practical needs

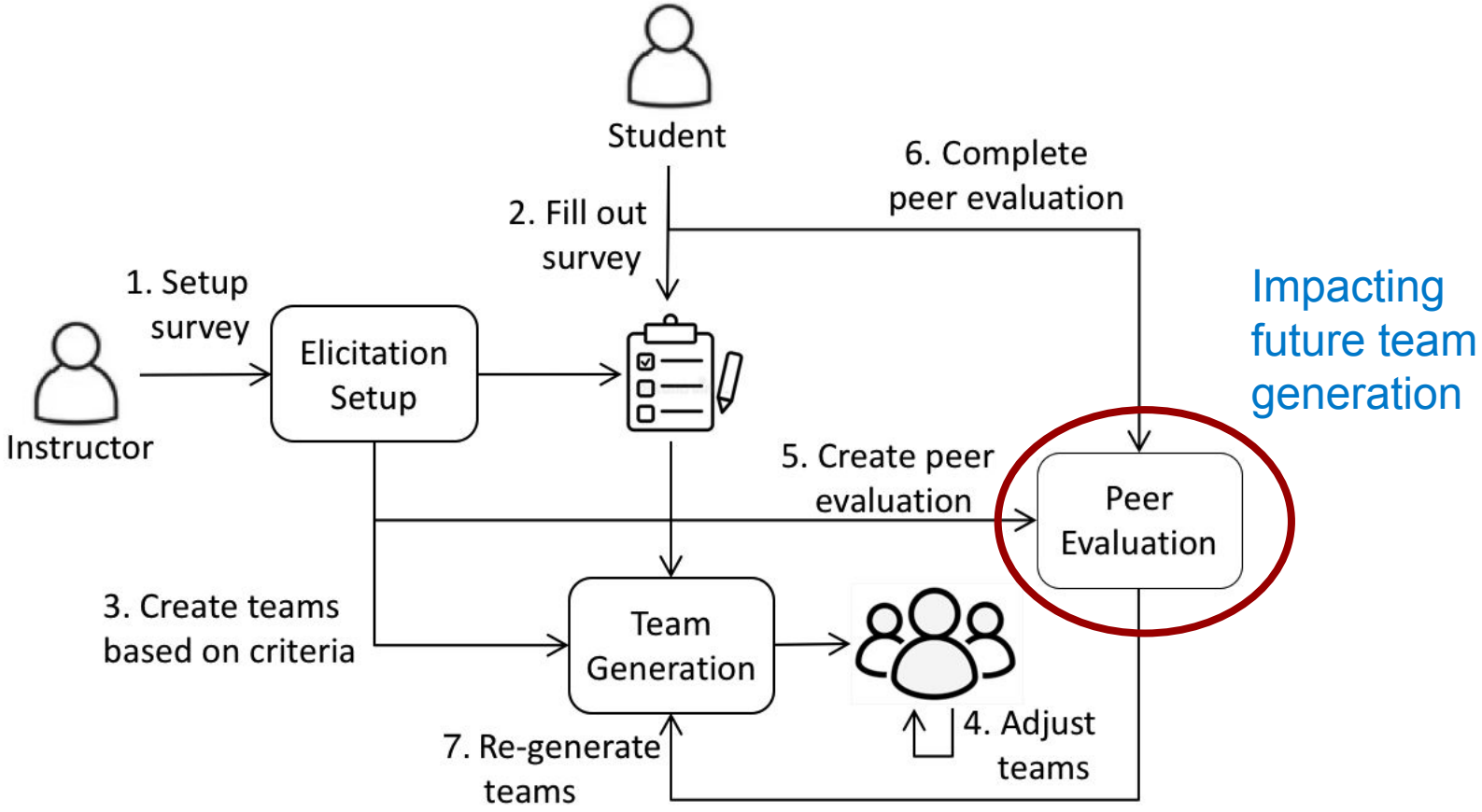
- Registration
- Unsolicited variables
- Personal requests

Team Formation Use Cases [CSEDU, 2022]



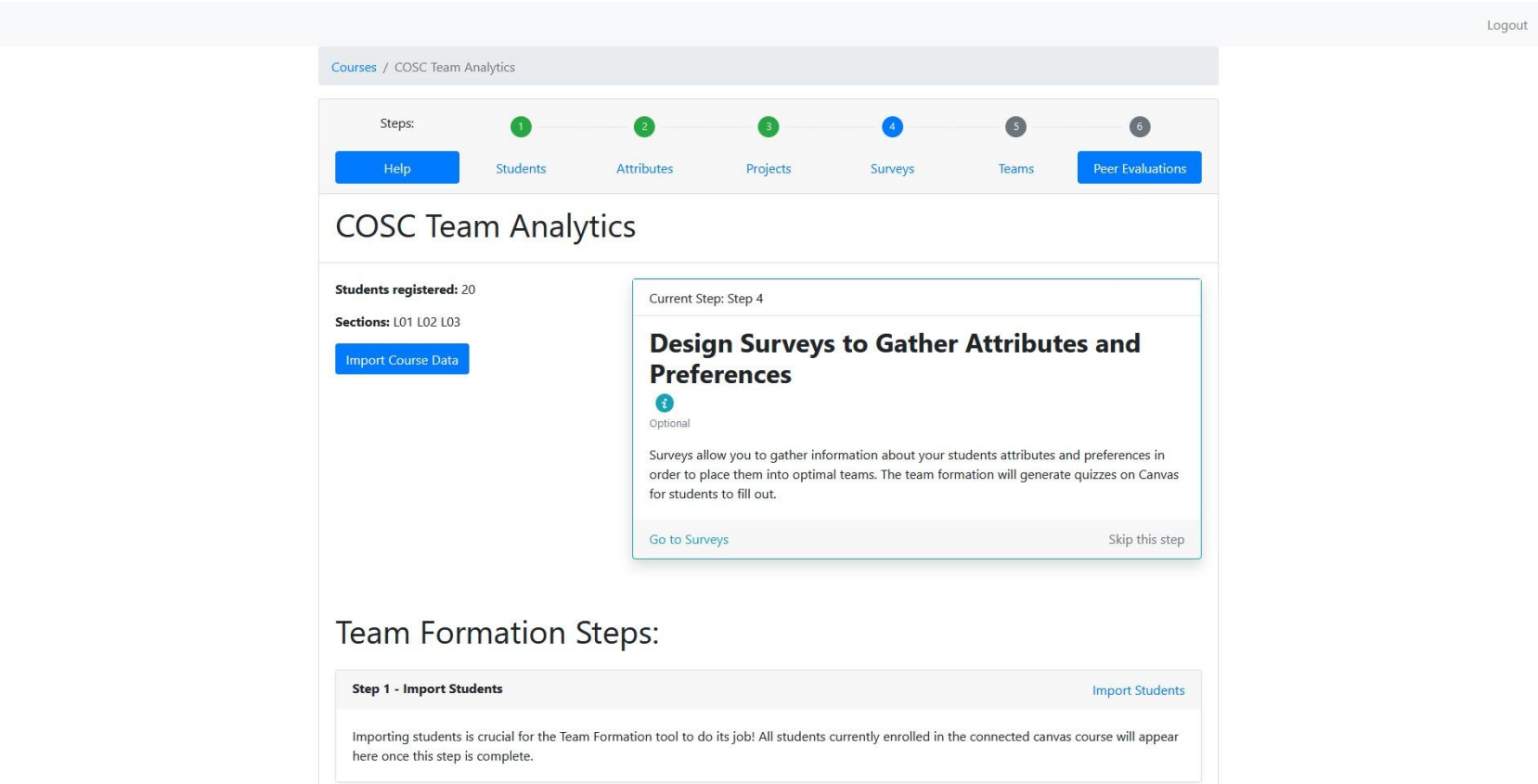
Encompass peer feedback

Team Formation Use Cases [CSEDU, 2022]

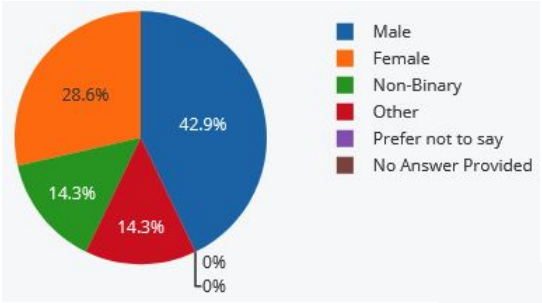


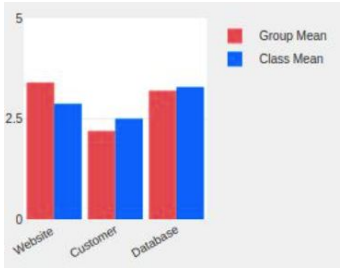
Impacting future team generation

Teamable Analytics Software [LAK 2022]



Teamable Analytics Software [LAK 2022]





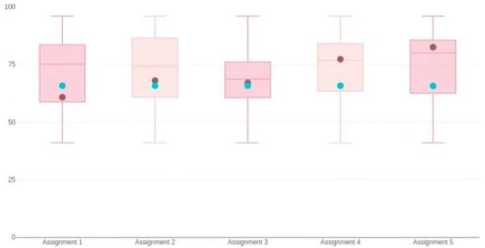
Operating Systems

Windows: 0

Linux: 3

MacOS: 4

Other: 0



Mobile Game - iOS

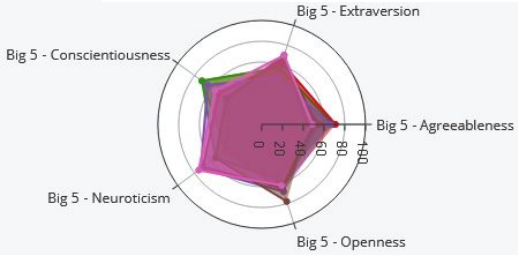
7 Students

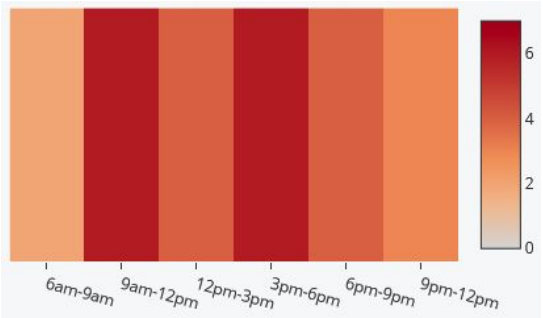
Capstone Project Preference

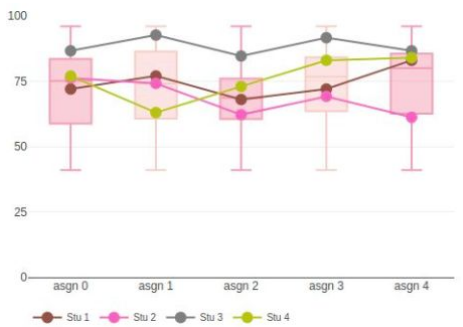
Satisfaction Level: 86%

View Members

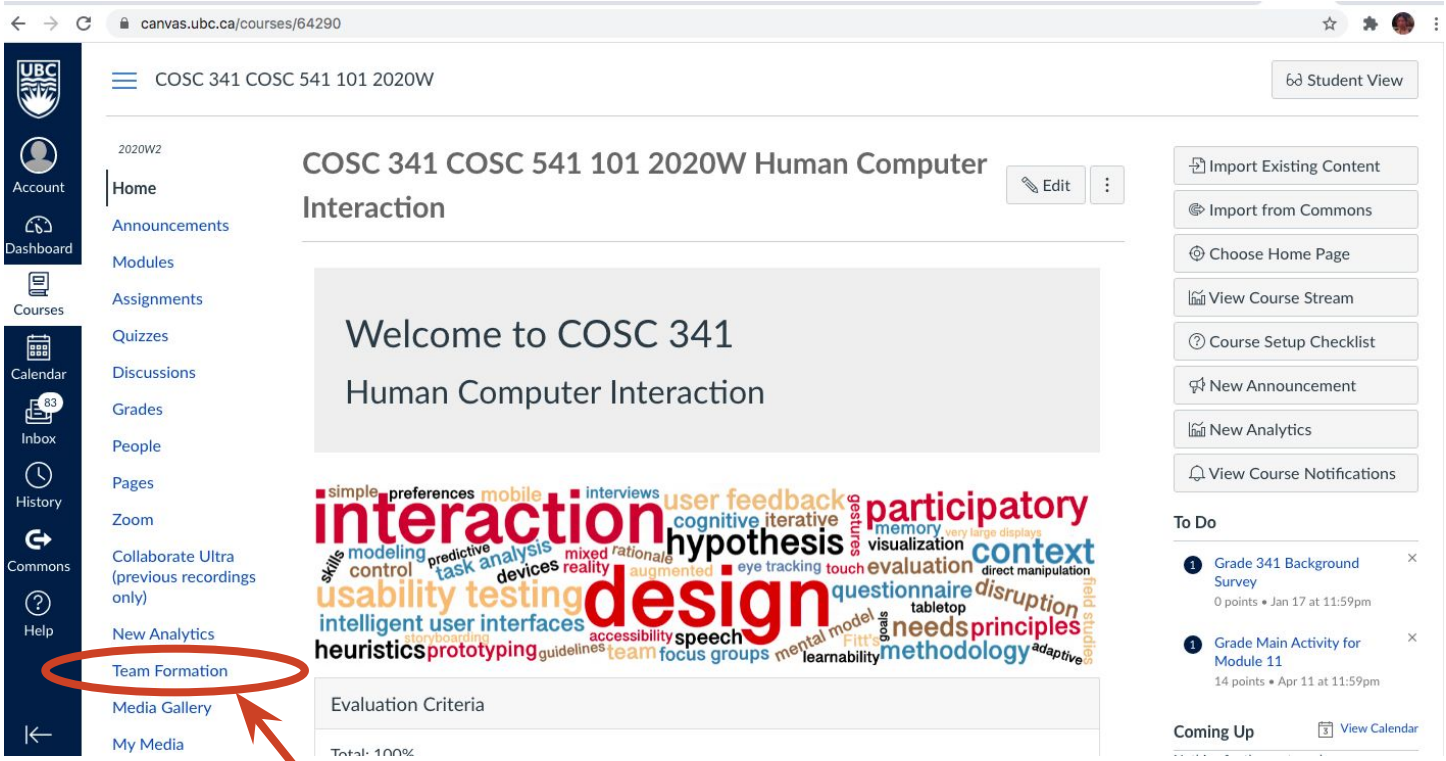
Name	Capstone Project Preference
CTLB	Mobile Game - iOS: ✔ Community Garden Planner: ✘
CTLC	Youth Sports Tournament Creator: ✘ Mobile Game - iOS: ✔
CTLD	Youth Sports Tournament Creator: ✘ Community Garden Planner: ✘







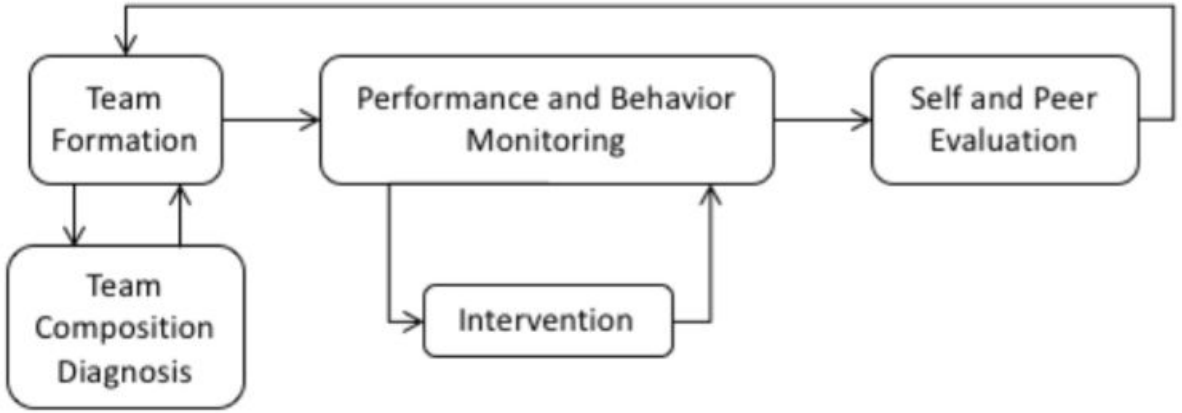
Teamable Analytics Software [LAK 2022]



Select from Canvas course shell

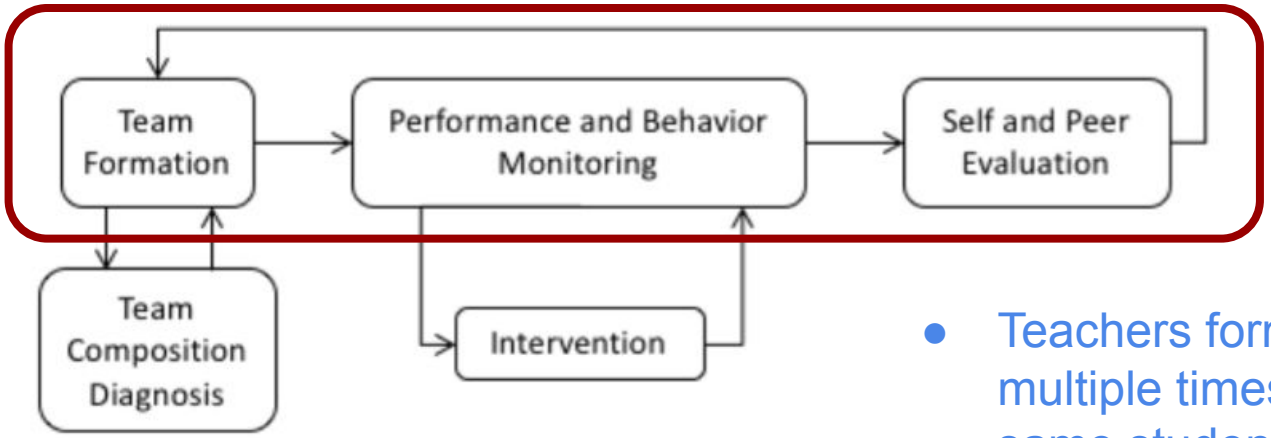
Need for Ongoing Team Monitoring [IJILT 2022]

- Team formation is just the first step
- Processes to support effective teamwork:



Need for Ongoing Team Monitoring [IJILT 2022]

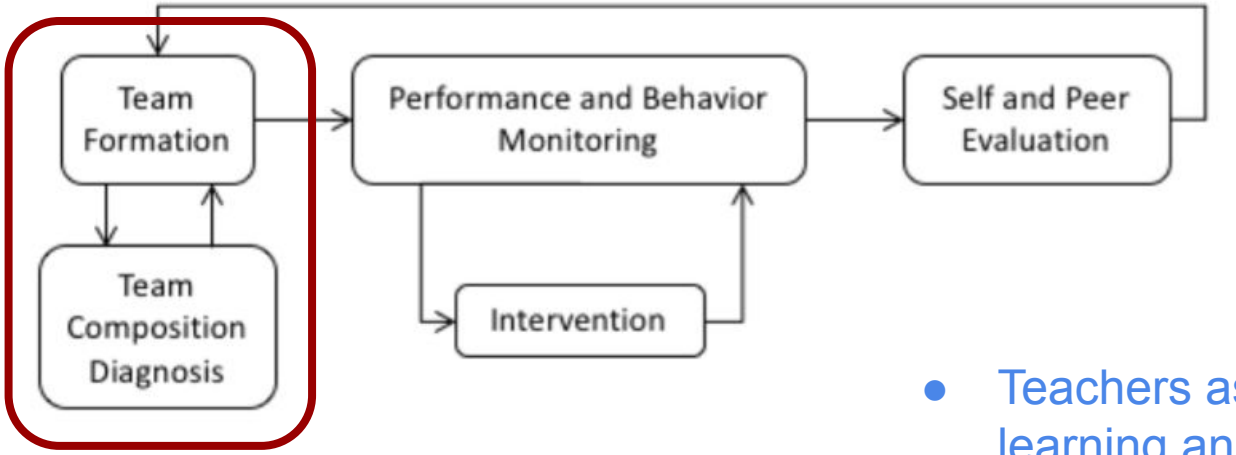
- Team formation is just the first step
- Processes to support effective teamwork:



- Teachers form teams multiple times with the same students
- Consider peer evaluation feedback in future team generations

Need for Ongoing Team Monitoring [IJILT 2022]

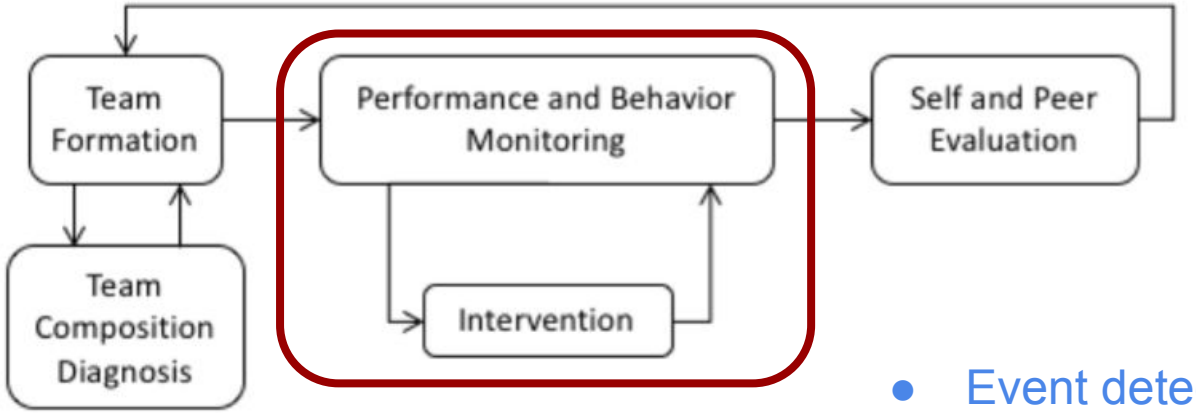
- Team formation is just the first step
- Processes to support effective teamwork:



- Teachers as audience for learning analytics
- Team composition diagnosis

Need for Ongoing Team Monitoring [IJILT 2022]

- Team formation is just the first step
- Processes to support effective teamwork:



- Event detection
- Collaboration modeling
- Team analytics prediction

Literature on Effective Teamwork Modeling

Team Stages

Quantitative Team Diagnosis

Team Characteristics

Our Synthesis of Team Concepts

Literature on Effective Teamwork Modeling

Team Stages

- Stages of Development
  [Tuckman 1965; Tuckman & Jensen 1977]
- Two-Stage Group Development
  [Bushe & Coetzer 2007]

Quantitative Team Diagnosis

Team Characteristics

Our Synthesis of Team Concepts

Literature on Effective Teamwork Modeling

Team Stages

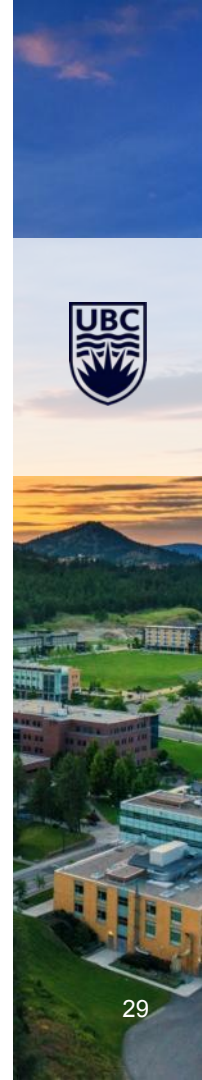
- Stages of Development
  [Tuckman 1965; Tuckman & Jensen 1977]
- Two-Stage Group Development
  [Bushe & Coetzer 2007]

Quantitative Team Diagnosis

Team Characteristics

- GRIP shared mental model [Raue et al. 2013]
  [Katzenback & Smith 1993]
- skills, accountability, commitment
- safety, structure, meaning [Google 2023; Adams 2002]
- interdependence, conflict res, safety, structure
  [Mickan & Rodger 2000]
- 7 org structure, 4 indiv, 7 team processes
- social loafing, interdependence, trust, shared mental model [Borrego et al. 2013]
- Lencioni model 5 dysfunctions
  [Lencioni & Stransky 2002]

Our Synthesis of Team Concepts



Literature on Effective Teamwork Modeling

Team Stages

- Stages of Development
  [Tuckman 1965; Tuckman & Jensen 1977]
- Two-Stage Group Development
  [Bushe & Coetzer 2007]

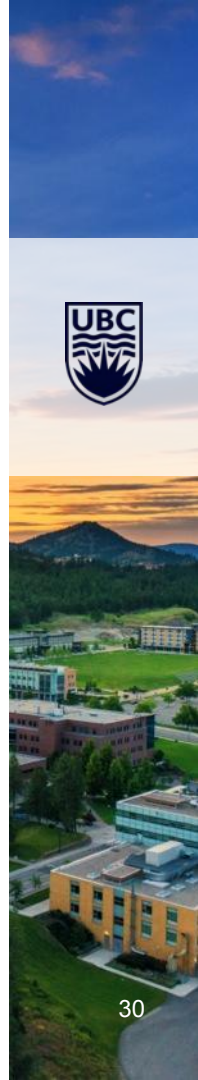
Quantitative Team Diagnosis

- CARE model [O'Neill et al. 2018; 2020]
- performance, behavior, attitude, style, corporate culture
  [Ross et al. 2008]

Team Characteristics

- GRIP shared mental model [Raue et al. 2013]
  [Katzenback & Smith 1993]
- skills, accountability, commitment
- safety, structure, meaning [Google 2023; Adams 2002]
- interdependence, conflict res, safety, structure
  [Mickan & Rodger 2000]
- 7 org structure, 4 indiv, 7 team processes
- social loafing, interdependence, trust, shared mental model [Borrego et al. 2013]
- Lencioni model 5 dysfunctions
  [Lencioni & Stransky 2002]

Our Synthesis of Team Concepts



Literature on Effective Teamwork Modeling

Team Stages

- Stages of Development [Tuckman 1965; Tuckman & Jensen 1977]
- Two-Stage Group Development [Bushe & Coetzer 2007]

Quantitative Team Diagnosis

- CARE model [O'Neill et al. 2018; 2020]
- performance, behavior, attitude, style, corporate culture [Ross et al. 2008]

Team Characteristics

- GRIP shared mental model [Raue et al. 2013] [Katzenback & Smith 1993]
- skills, accountability, commitment
- safety, structure, meaning [Google 2023; Adams 2002]
- interdependence, conflict res, safety, structure [Mickan & Rodger 2000]
- 7 org structure, 4 indiv, 7 team processes
- social loafing, interdependence, trust, shared mental model [Borrego et al. 2013]
- Lencioni model 5 dysfunctions [Lencioni & Stransky 2002]

Our Synthesis of Team Concepts

- shared mental model
- trust
  - safety, belonging, commitment, …
- interdependence
- motivation
- diversity of skills
- external factors

Literature on Effective Teamwork Modeling

Team Stages

- Stages of Development [Tuckman 1965; Tuckman & Jensen 1977]
- Two-Stage Group Development [Bushe & Coetzer 2007]

Quantitative Team Diagnosis

- CARE model [O'Neill et al. 2018; 2020]
- performance, behavior, attitude, style, corporate culture [Ross et al. 2008]

Team Characteristics

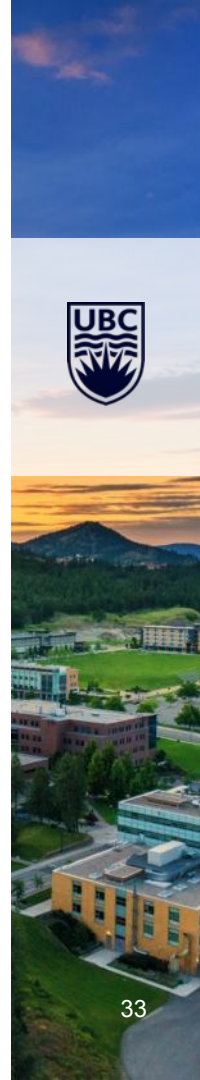
- GRIP shared mental model [Raue et al. 2013] [Katzenback & Smith 1993]
- skills, accountability, commitment
- safety, structure, meaning [Google 2023; Adams 2002]
- interdependence, conflict res, safety, structure [Mickan & Rodger 2000]
- 7 org structure, 4 indiv, 7 team processes
- social loafing, interdependence, trust, shared mental model [Borrego et al. 2013]
- Lencioni model 5 dysfunctions [Lencioni & Stransky 2002]

Our Synthesis of Team Concepts

- shared mental model
- trust
  - safety, belonging, commitment, …
- interdependence
- motivation
- diversity of skills
- external factors

Understanding Data Needs for Team Modeling [FIE 2023]

- A ***dynamic Bayesian modeling*** approach [Pearl, 1998; Pearl, 2011]
  - Represent uncertain world knowledge intuitively
  - Well-established mathematical foundations
  - Create personalized student models and individual team models

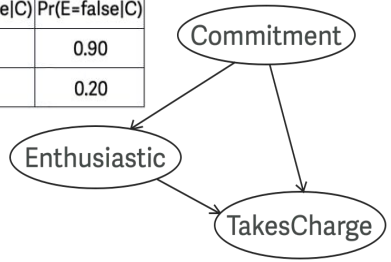


Understanding Data Needs for Team Modeling [FIE 2023]

- A ***dynamic Bayesian modeling*** approach [Pearl, 1998; Pearl, 2011]
  - Represent uncertain world knowledge intuitively
  - Well-established mathematical foundations
  - Create personalized student models and individual team models

Pr(C=Low)	Pr(C=High)
0.50	0.50

C	Pr(E=true|C)	Pr(E=false|C)
Low	0.10	0.90
High	0.80	0.20



C	E	Pr(TC=true|C,E)	Pr(TC=false|C,E)
Low	true	0.45	0.55
Low	false	0.01	0.99
High	true	0.90	0.10
High	false	0.60	0.40

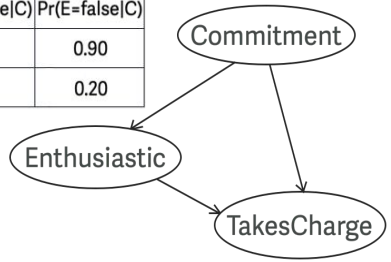
If the student is highly committed, how likely are they to take charge?

Understanding Data Needs for Team Modeling [FIE 2023]

- A ***dynamic Bayesian modeling*** approach [Pearl, 1998; Pearl, 2011]
  - Represent uncertain world knowledge intuitively
  - Well-established mathematical foundations
  - Create personalized student models and individual team models

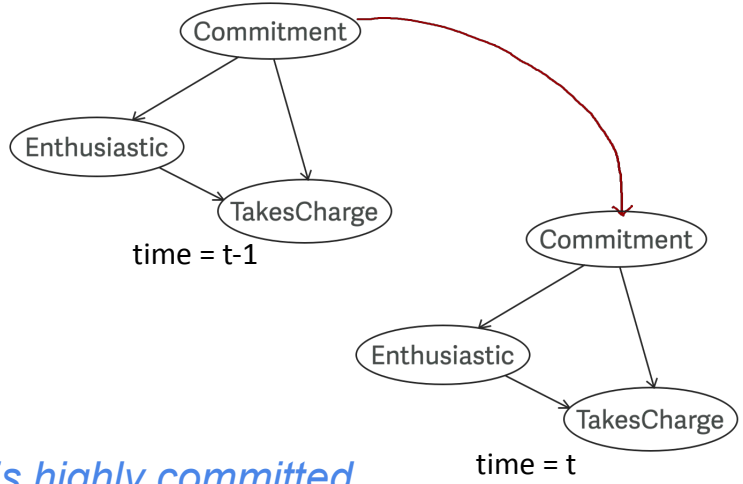
Pr(C=Low)	Pr(C=High)
0.50	0.50

C	Pr(E=true|C)	Pr(E=false|C)
Low	0.10	0.90
High	0.80	0.20



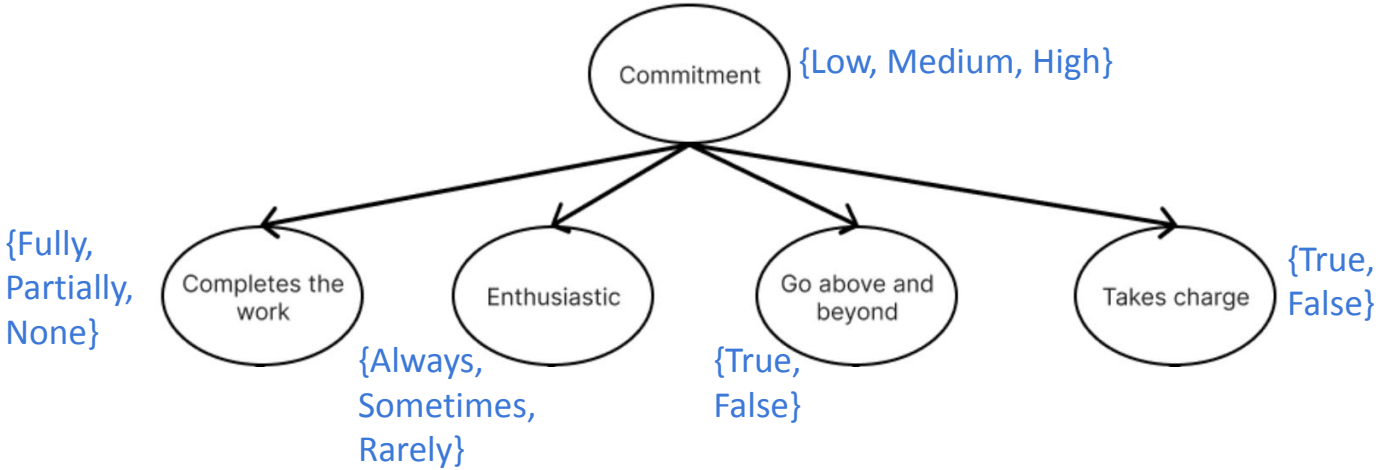
C	E	Pr(TC=true|C,E)	Pr(TC=false|C,E)
Low	true	0.45	0.55
Low	false	0.01	0.99
High	true	0.90	0.10
High	false	0.60	0.40

If the student is highly committed, how likely are they to take charge?



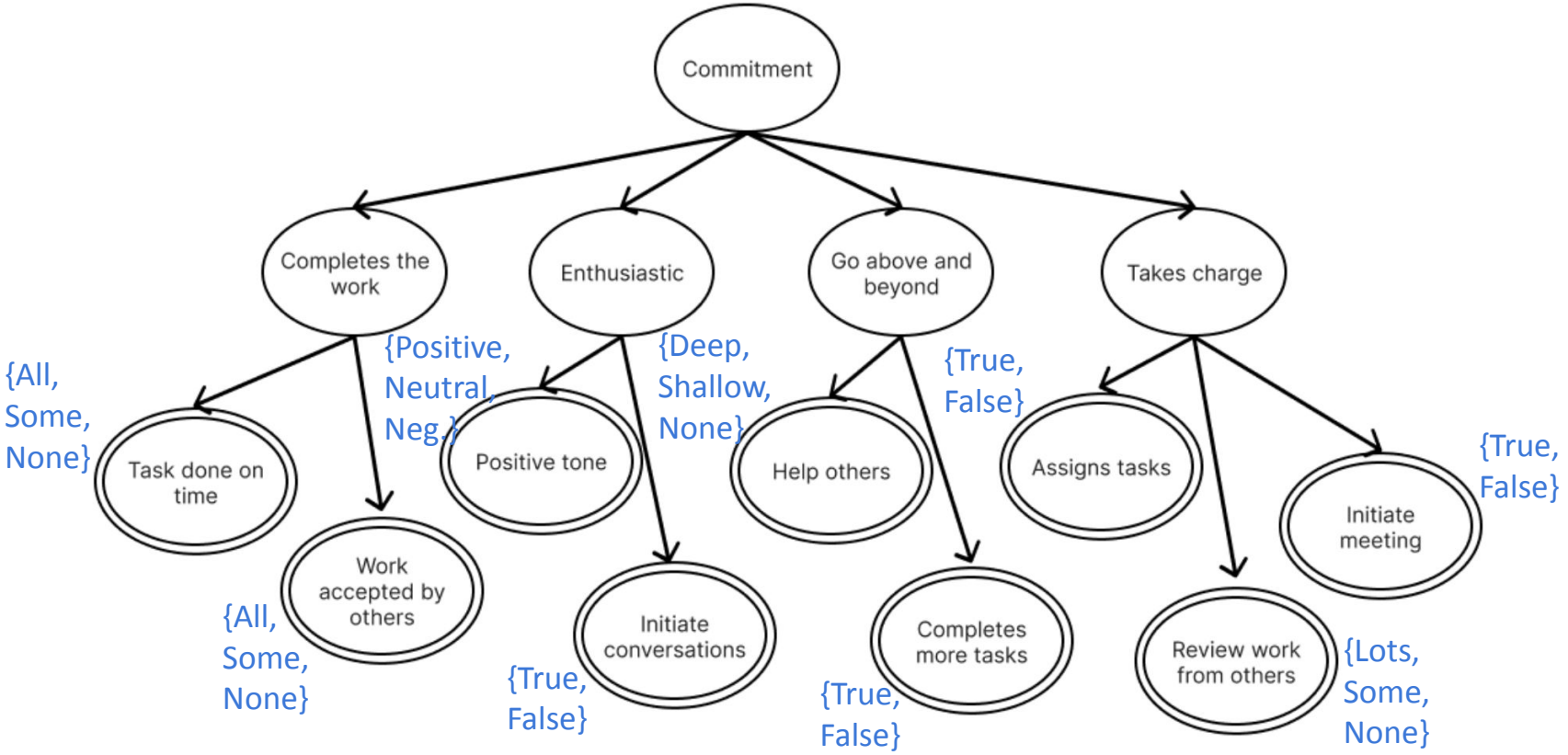
If the student is highly committed, how likely are they to continue being highly committed?

Closer Look at the Commitment Model



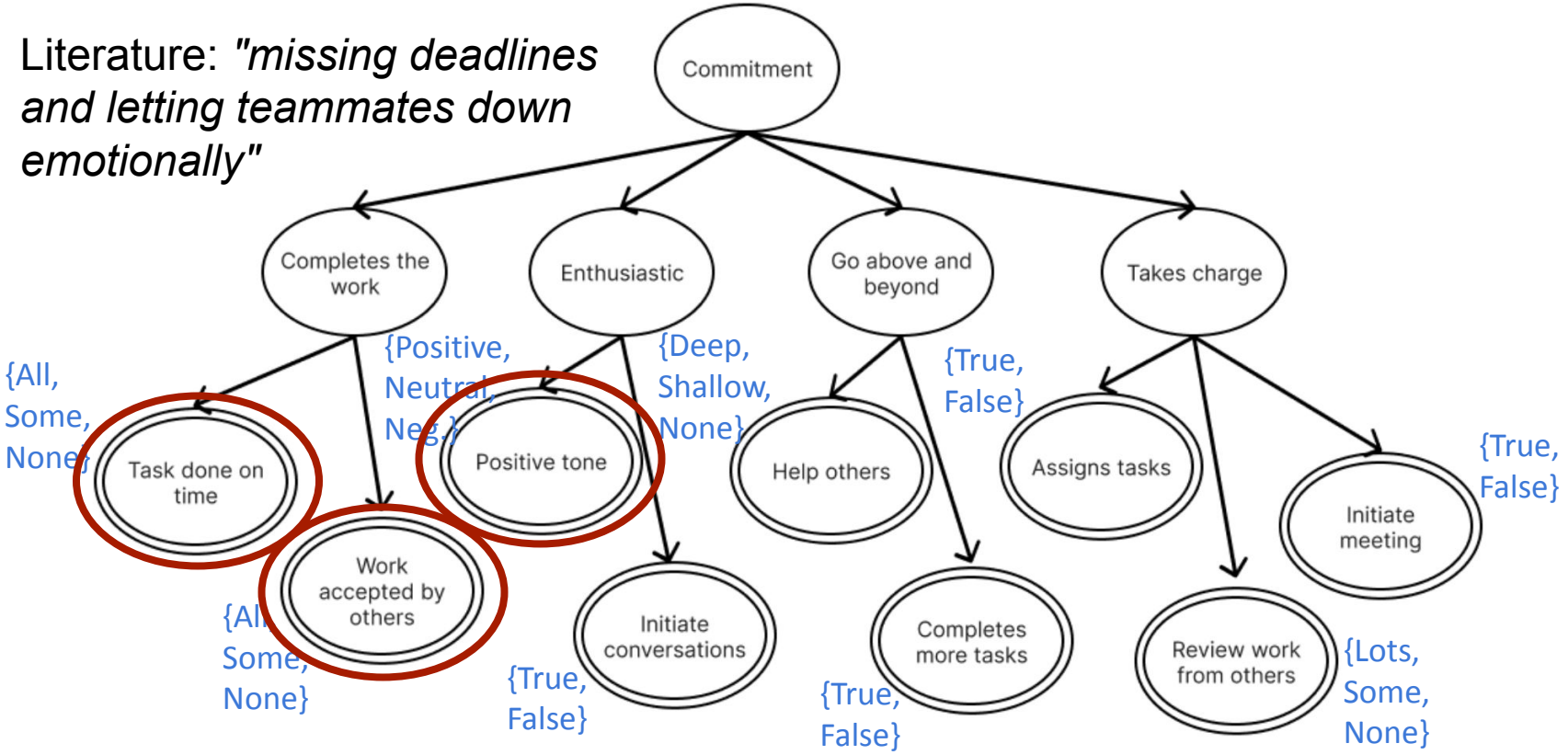
Literature: *"feeling of responsibility for the team's work"*

Closer Look at the Commitment Model



Closer Look at the Commitment Model

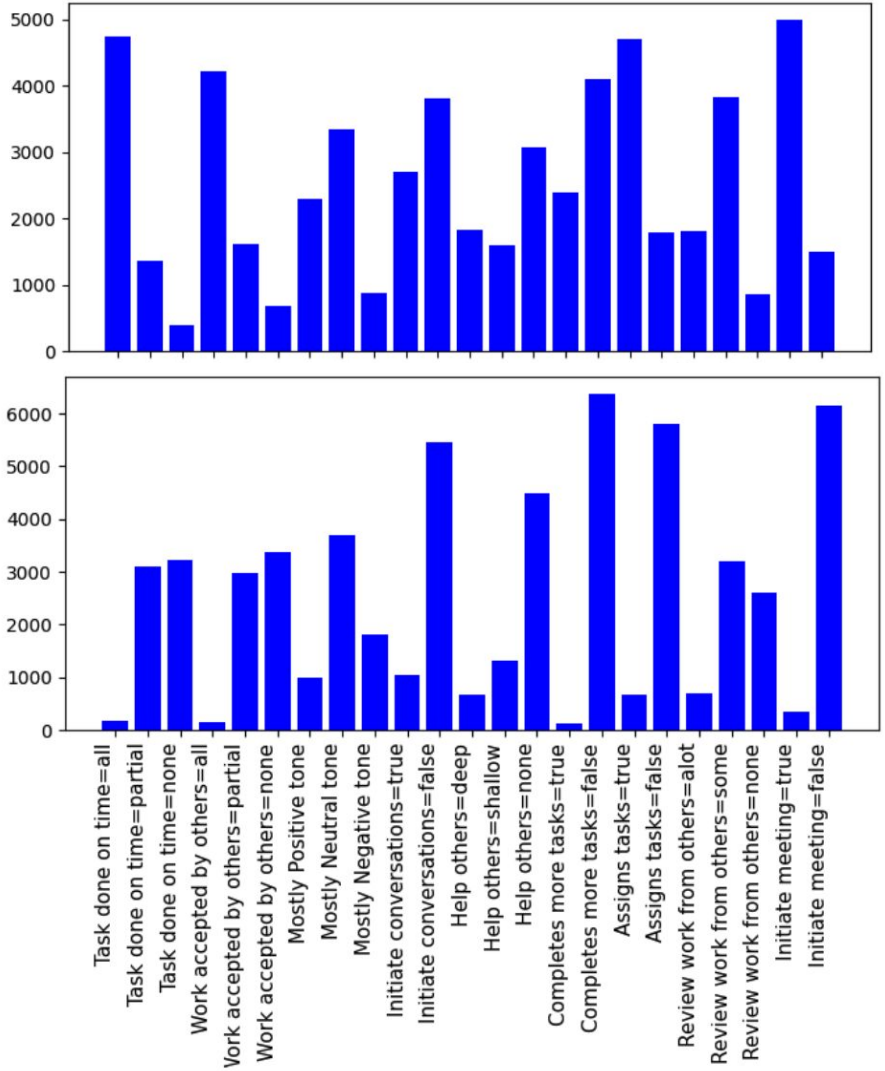
Literature: *"missing deadlines and letting teammates down emotionally"*



Simulation Results

Commitment = High

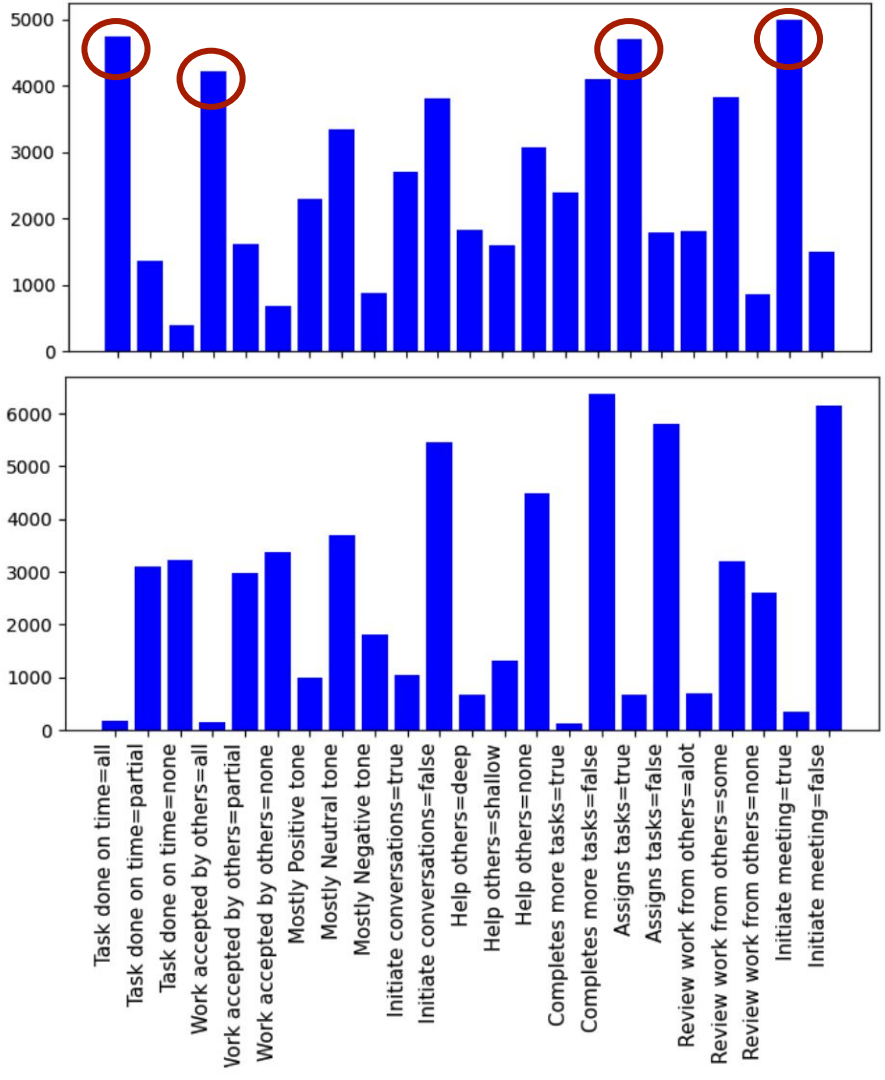
Commitment = Low



Simulation Results

Commitment = High

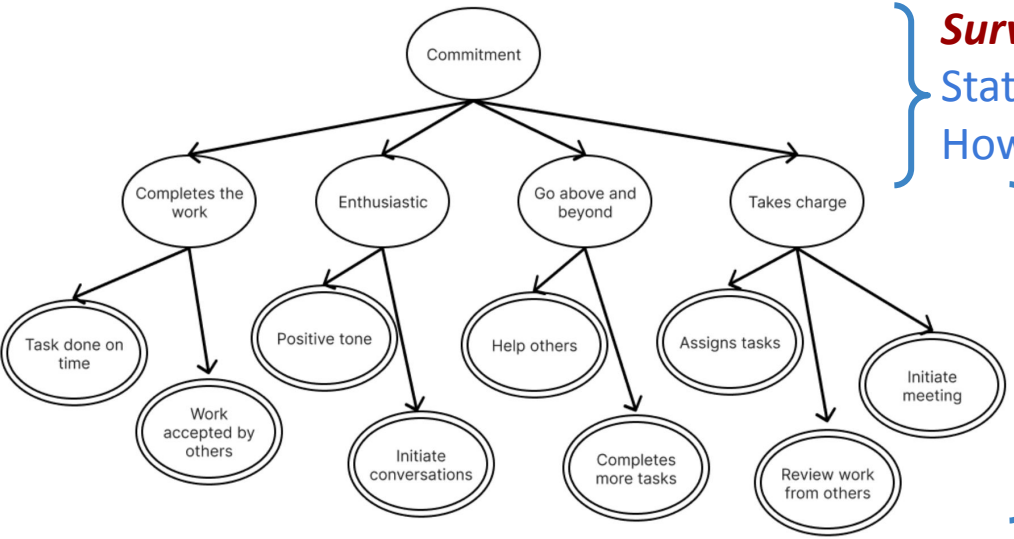
Commitment = Low



- ***Responsible*** (left circles):
  - work on time, good quality
- ***Leadership*** (right circles):
  - assigns tasks, initiate meetings

Model Data Needs

- Design controlled experiments or collect field data to populate model parameters
  - Every conditional probability table is a quantitative relationship between two or more variables

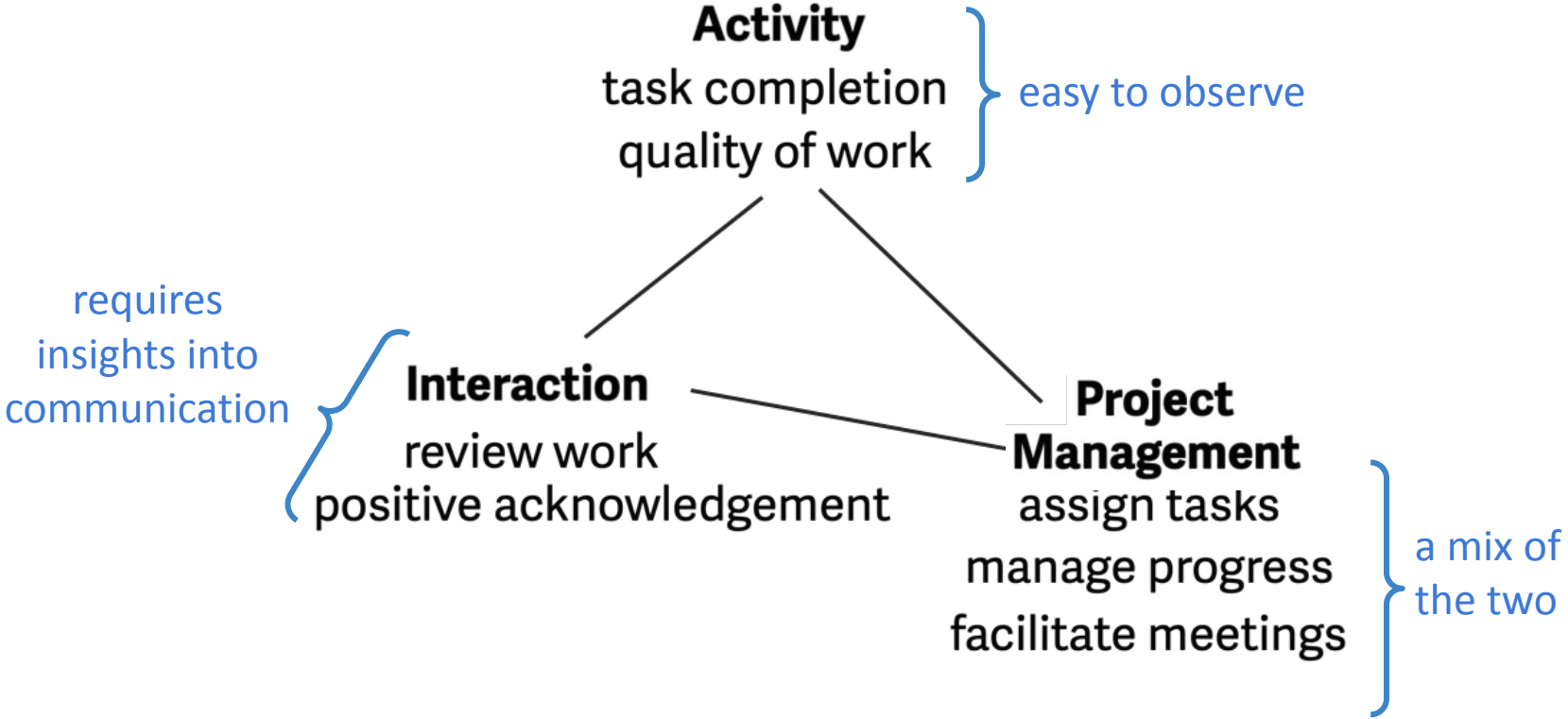


Survey:
State your commitment level.
How likely are you to [type]

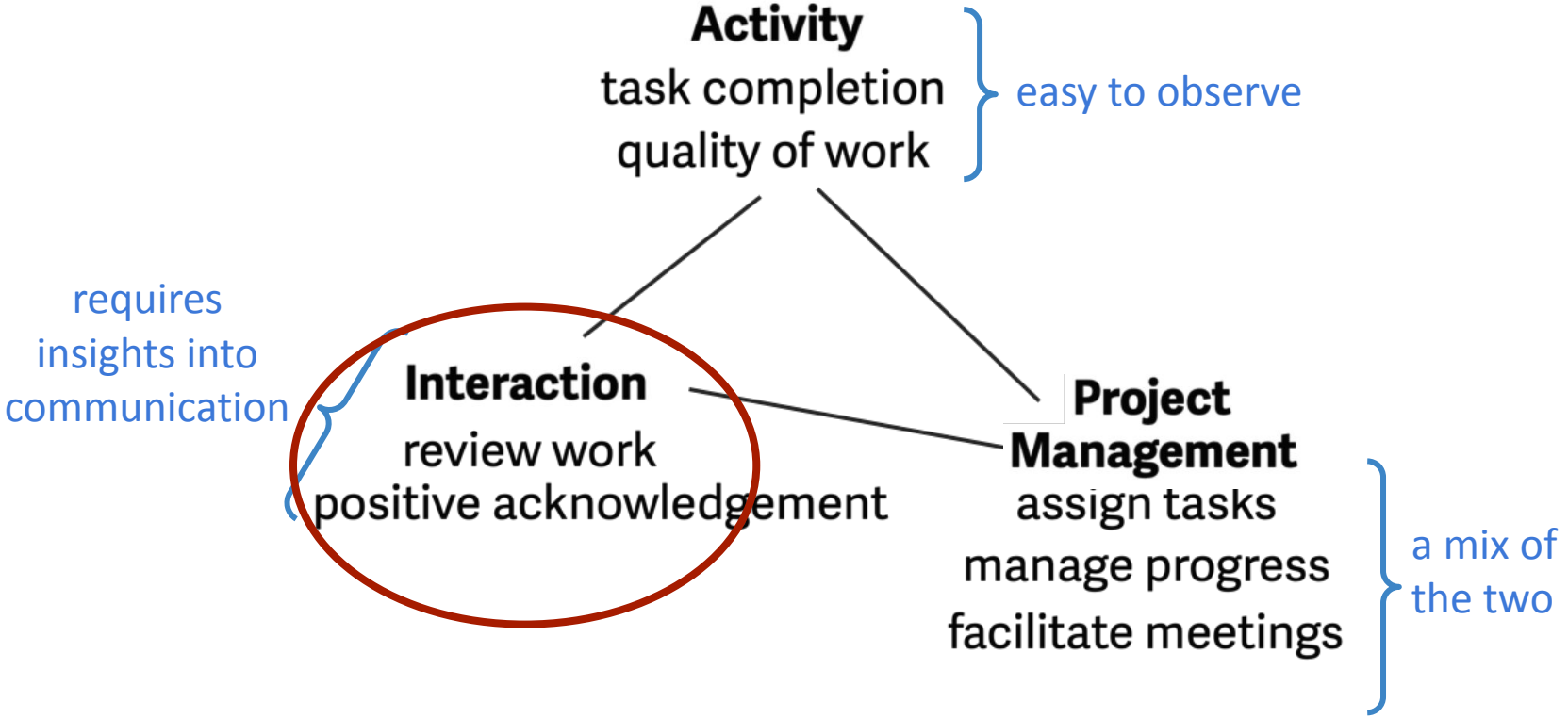
Survey:
When you want to _____, how likely are you to [action]

Empirical:
Knowing you are _____, count instances of each action

Types of Data Needs

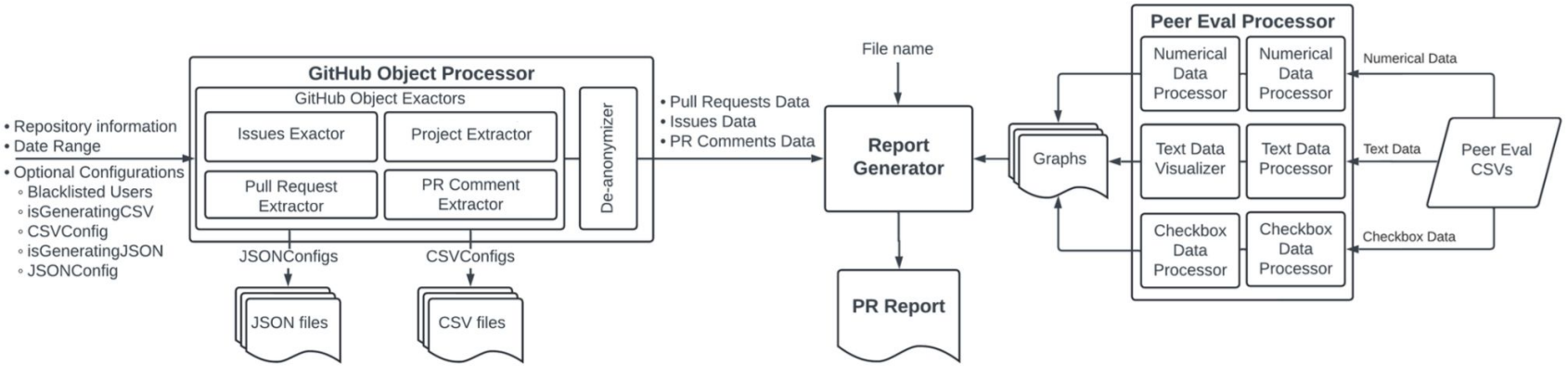


Types of Data Needs



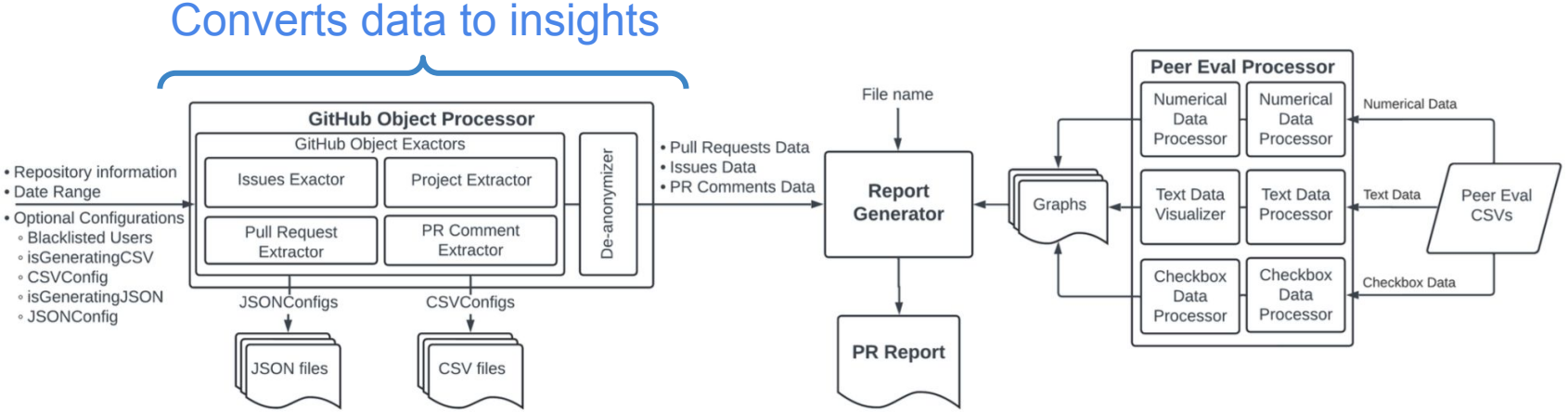
GitHub Collaboration Analysis [Forthcoming, 2024]

- GitHub as an environment to observe ***natural*** collaboration activities
- System architecture:



GitHub Collaboration Analysis [Forthcoming, 2024]

- GitHub as an environment to observe ***natural*** collaboration activities
- System architecture:

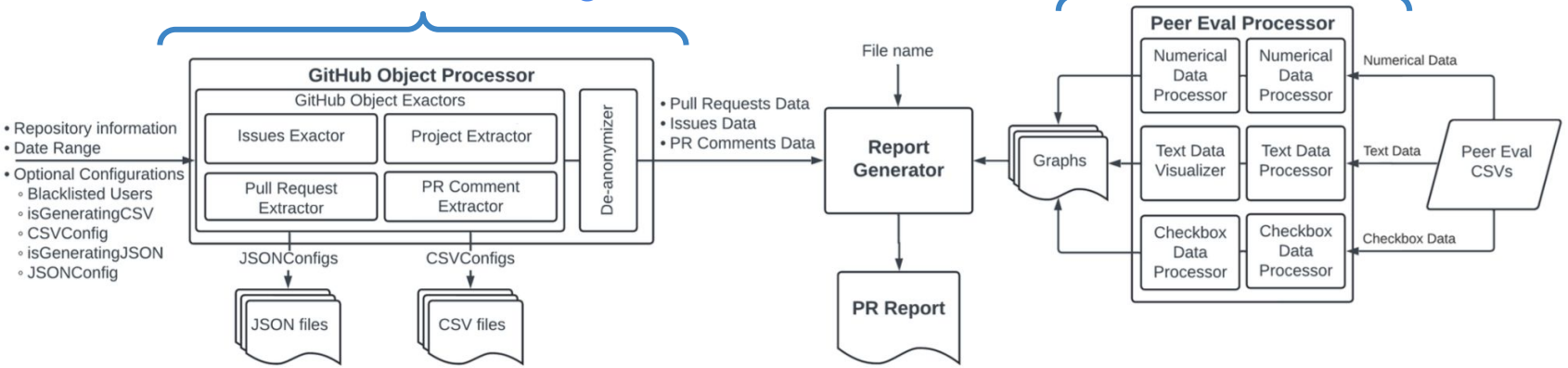


GitHub Collaboration Analysis [Forthcoming, 2024]

- GitHub as an environment to observe ***natural*** collaboration activities
- System architecture:

Converts data to insights

Considers subjective student feedback

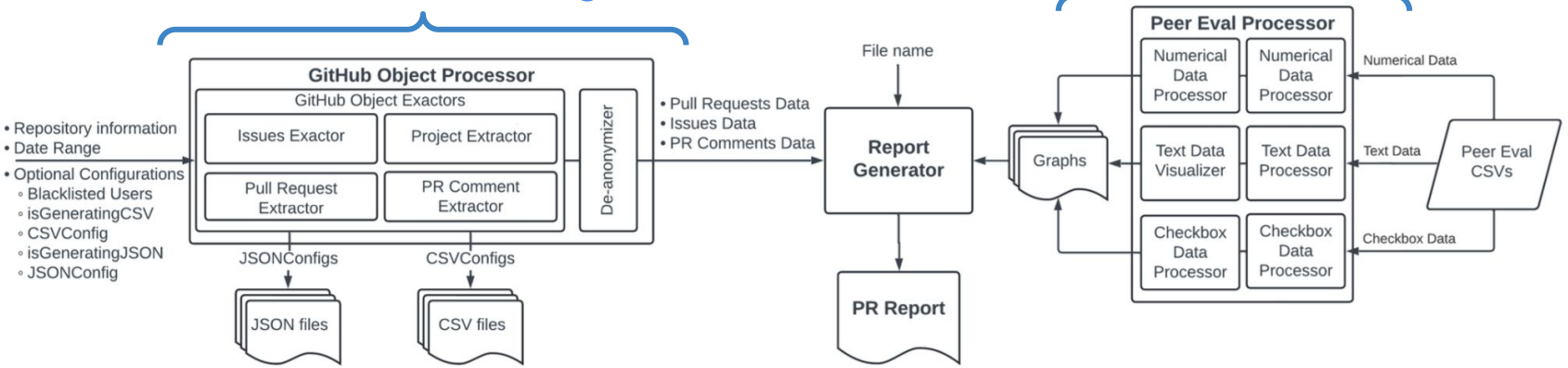


GitHub Collaboration Analysis [Forthcoming, 2024]

- GitHub as an environment to observe ***natural*** collaboration activities
- System architecture:

Converts data to insights

Considers subjective student feedback



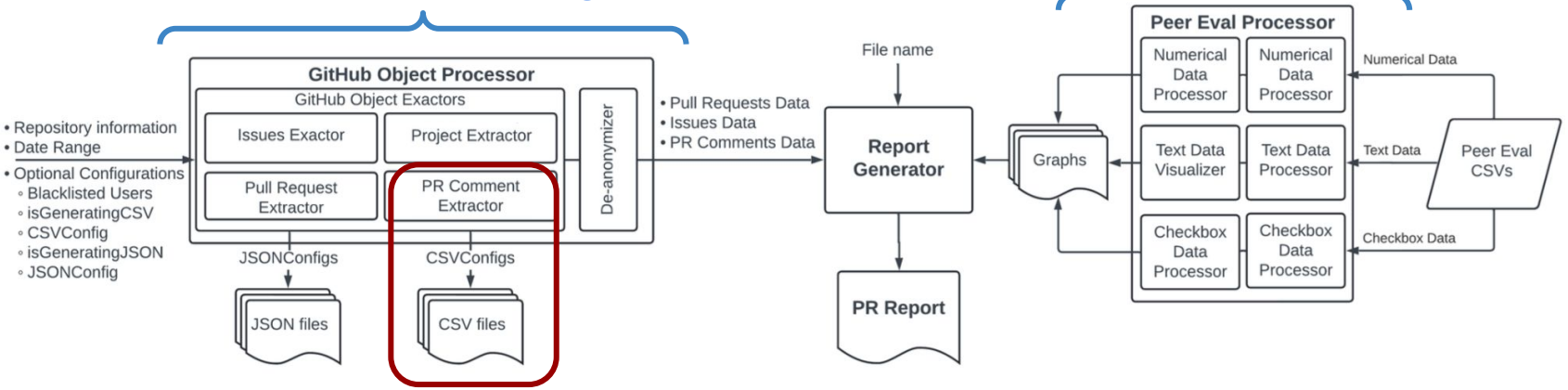
Team analytics to support instructor diagnosis

GitHub Collaboration Analysis [Forthcoming, 2024]

- GitHub as an environment to observe ***natural*** collaboration activities
- System architecture:

Converts data to insights

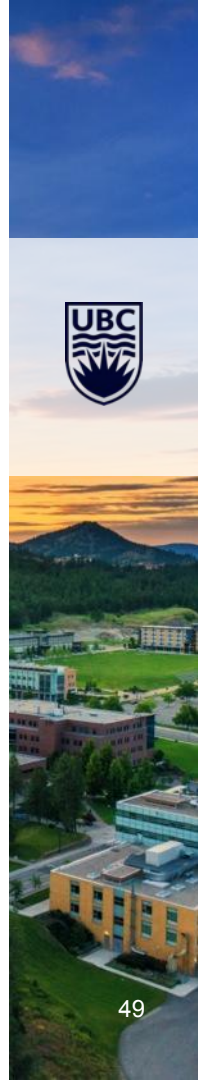
Considers subjective student feedback



Team analytics to support instructor diagnosis

Diversity in Teams

- Many educators agree that team diversity is important
- Conflicting results that diversity has on team outcomes and how diversity is defined [Horwitz & Horwitz, 2007]



Diversity in Teams

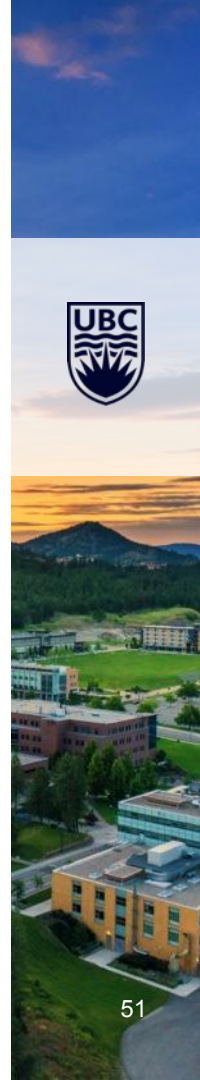
- Many educators agree that team diversity is important
- Conflicting results that diversity has on team outcomes and how diversity is defined [Horwitz & Horwitz, 2007]
- Gender-diverse and racial-diverse teams often result in more conflict where minoritized members are:
  - Confronted with microaggressions [Ong et al. 2011]
  - Perceived as less skillful than peers in homogeneous teams [Pelled, 1996; Baugh, 1997]
  - Treated with bias
    - not heard, not given leadership roles, pressured to change behaviors [Grindstaff & Mascarenhas, 2019]
- Problems are exacerbated when minorities are ***tokenized*** [Kanter 1977; Spangler et al. 1978; Thompson & Sekaquaptewa 2002]

Software Engineering Team Collaboration

- Team members work on a programming project (e.g., hosted on GitHub)

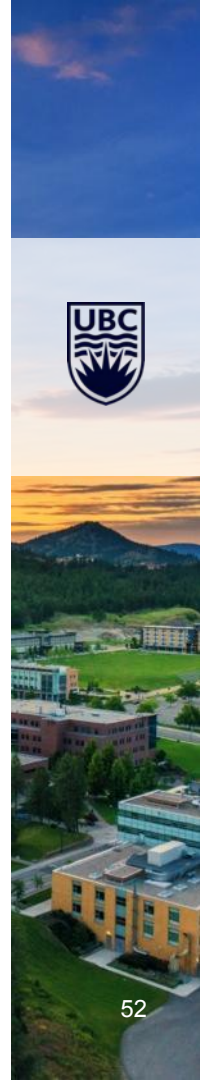
- Development cycle:
  - Members simultaneously pull the master version
  - Members work independently on additional features locally
  - Members ask for ***code reviews*** from others
  - If approved, new code is pushed and merged to create a new master version

- Literature reveals issues with gender-diverse professional teams, but limited studies on student teams and other diversity factors
  [Rodríguez-Pérez et al., 2021; Graßl et al., 2023]



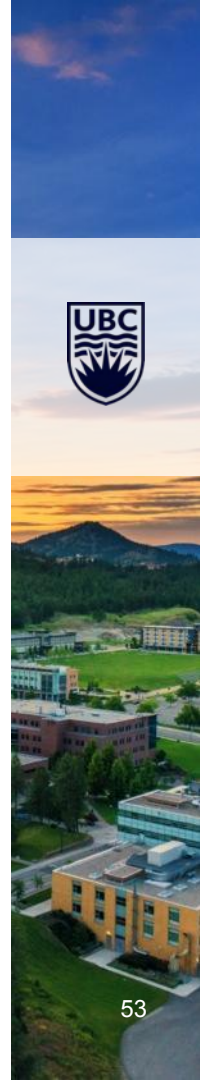
Communication in Student Teams [Forthcoming, 2024]

- Code reviews manifest as asynchronous messages between team members
- Collected this data from 105 students split into 22 teams
  - 86 males, 15 females, 1 non-binary, 3 no answer
  - 63 racial minorities and 42 European descent
  - 11 racialized gender minorities



Communication in Student Teams [Forthcoming, 2024]

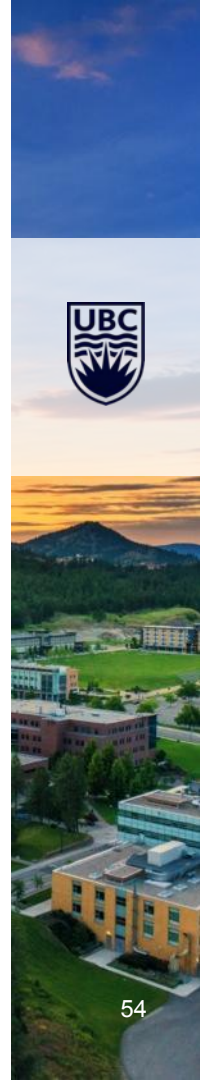
- Code reviews manifest as asynchronous messages between team members
- Collected this data from 105 students split into 22 teams
  - 86 males, 15 females, 1 non-binary, 3 no answer
  - 63 racial minorities and 42 European descent
  - 11 racialized gender minorities
- A team is **diverse for a learner characteristic** if at least 2 members differ
  - 12 gender-diverse teams vs. 10 all-male teams
  - 16 racially diverse teams vs. 6 racially homogeneous teams (5 were all racial minorities, 1 all European descent)
  - 8 teams had 1+ racialized gender minorities vs. 14 teams without intersectional members



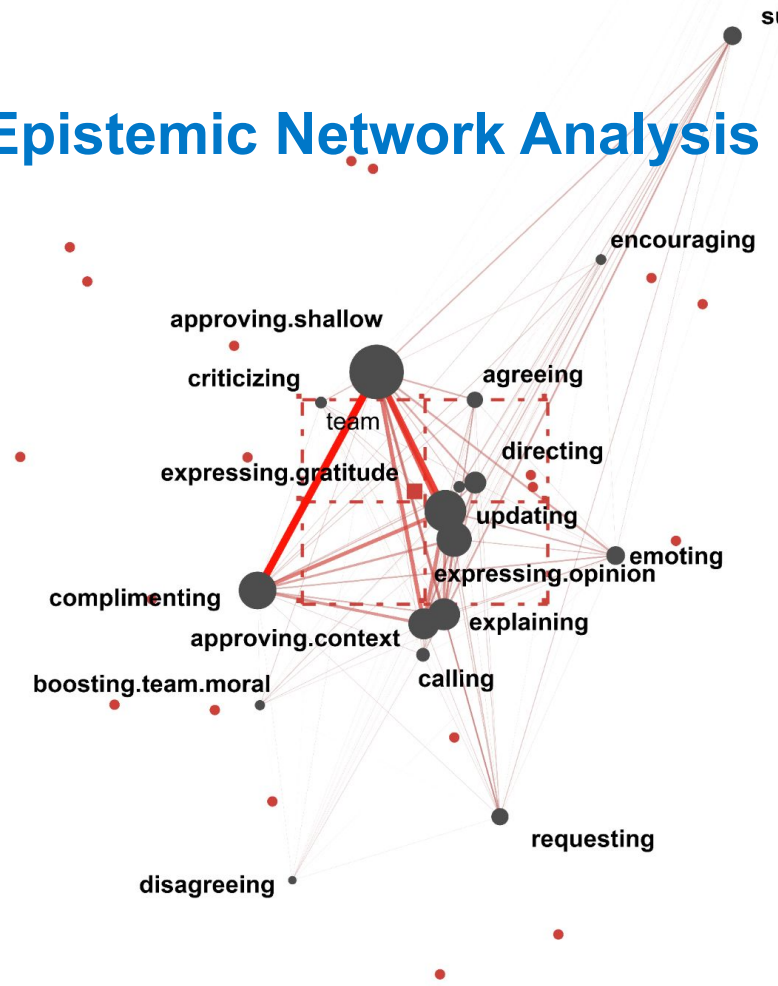
Communication in Student Teams [Forthcoming, 2024]

Table 1: Codebook of communicative acts from the code review data.

Code	Definition	Example
Agreeing	Say something in agreement	Alrite sounds good!
Apologizing	Recognize a mistake	My bad on this one.
Approving context	Approve with justification	Added templates, looks good!
Approving shallow	Approve, no justification	lgtm / Approved.
Boosting Team Morale	Encourage the team	This team is on fire
Calling	Reference a team member	jessica61 Any comments?
Complimenting	Praise something	Well done logs!
Criticizing	Criticize without solutions	Doesn't work on windows
Directing	Give specific instructions	Remove this. See above.
Disagreeing	Say something in opposition	Hmm actually, no.
Emoting	Express emotions	Yah what lol? / Haha odd :)
Encouraging	Encourage a teammate	Well done this week as always!
Explaining	Explain or clarify	Since we use Patternfly
Expressing Gratitude	Say thanks	Cool, thanks for doing this
Expressing Opinion	Give an opinion	It's my personal preference
Requesting	Ask a question	Are we using tailwind?
Suggesting	Give a suggestion	This could be just optional?
Updating	Provide a status update	Fixed bracket.



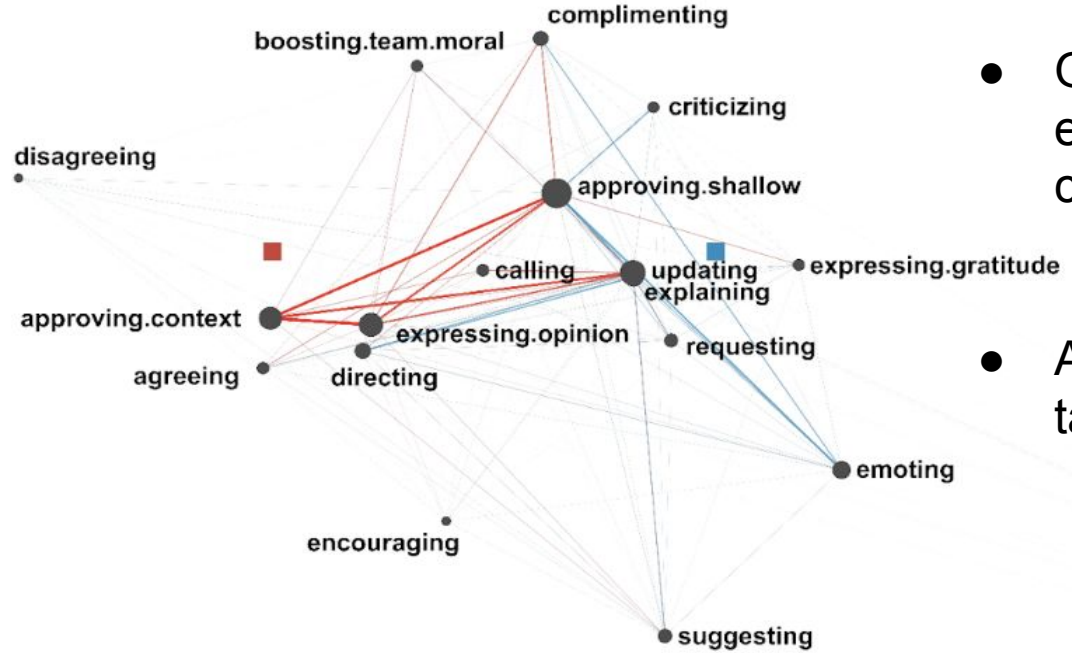
Epistemic Network Analysis (ENA)



- **Red** dots are teams
  - Square is the average team
- **Black** dots are codes
  - Larger ~ more occurrences
- Lines represent co-occurrence of codes in a window
  - Thickness ~ higher frequency

> pr_id

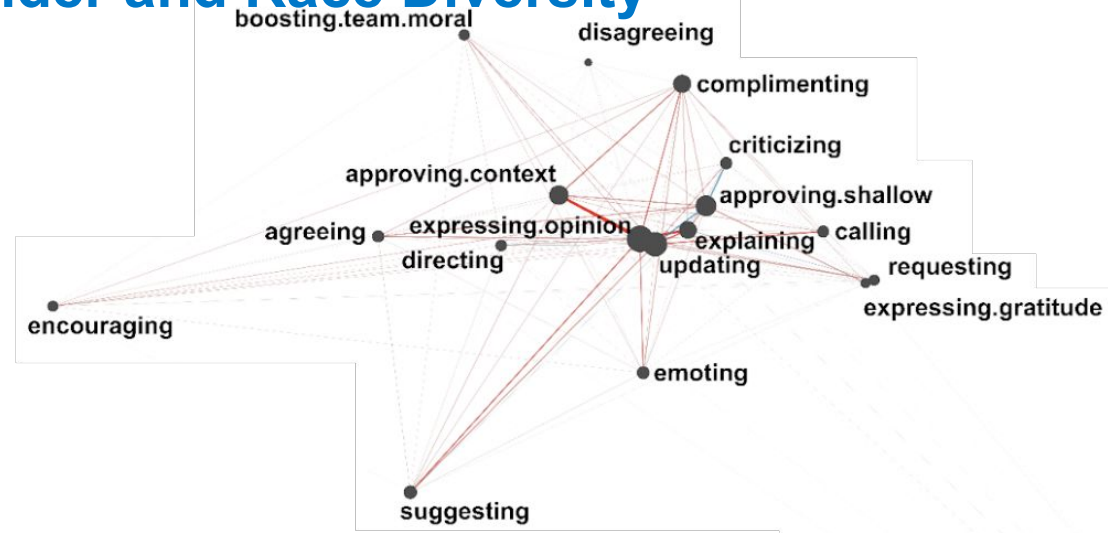
Gender Diversity



- Gender-diverse teams (**blue**) engage in social relational communication
- All-male teams (**red**) focus on task-oriented communication

0 – 1

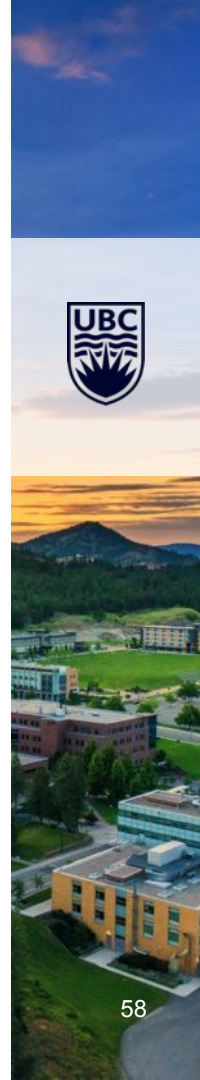
Gender and Race Diversity



- Intersectional teams (**blue**) show stronger connections for criticizing, approving shallow, and updating
- Non-intersectional teams (**red**) show task oriented patterns with more complimenting

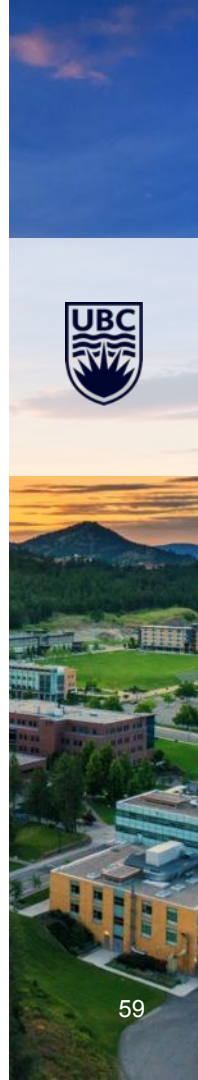
Discussion

- ***Categorization-Elaboration Model*** [van Knippenberg & van Ginkel, 2010]
  - Postulates information elaboration as a core process between diversity and performance
  - Moderators: member motivation, member ability, task complexity, and ***intergroup bias***
  - Presence of intergroup bias may surface as conflict among group members due to relationship conflict and task conflict [Jehn, 1995]



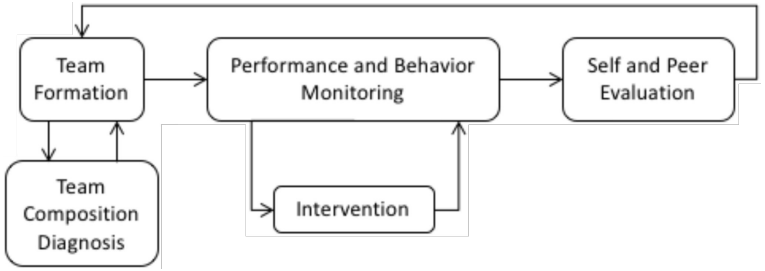
Discussion

- ***Categorization-Elaboration Model*** [van Knippenberg & van Ginkel, 2010]
  - Postulates information elaboration as a core process between diversity and performance
  - Moderators: member motivation, member ability, task complexity, and ***intergroup bias***
  - Presence of intergroup bias may surface as conflict among group members due to relationship conflict and task conflict [Jehn, 1995]
- Race (alone) may not be a salient factor in student software teams (in Canada)
- Gender-diverse team patterns suggest presence of intergroup bias
- Further analysis needed at student-level



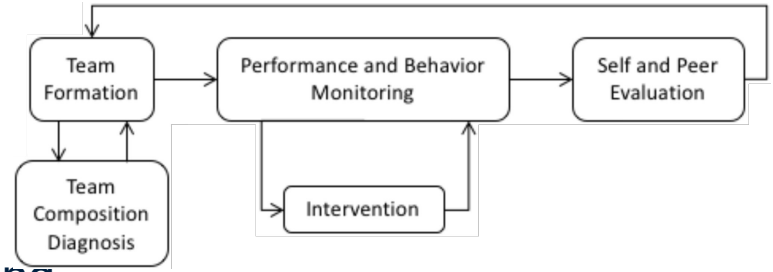
Summary

- Teachers as the analytics audience:
  - Analytics for diagnosing team compositions
  - Regenerate teams based on peer feedback
  - **Exploring:**
    - Trust in AI-generated teams for classroom use



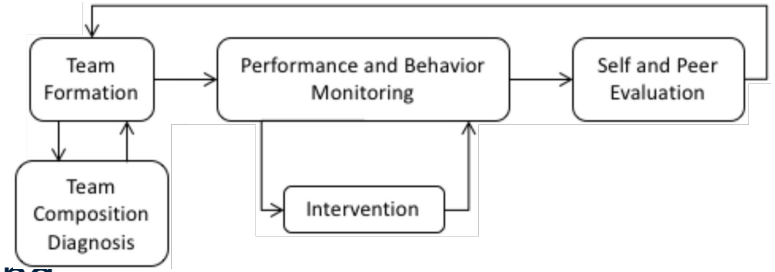
Summary

- Teachers as the analytics audience:
  - Analytics for diagnosing team compositions
  - Regenerate teams based on peer feedback
  - **Exploring:**
    - Trust in AI-generated teams for classroom use
- Students as the analytics audience:
  - Analytics for ongoing team monitoring
  - **Exploring:**
    - Student-level communication patterns
    - Detecting at-risk behaviors
    - Alerting instructors to appropriate interventions



Summary

- Teachers as the analytics audience:
  - Analytics for diagnosing team compositions
  - Regenerate teams based on peer feedback
  - **Exploring:**
    - Trust in AI-generated teams for classroom use
- Students as the analytics audience:
  - Analytics for ongoing team monitoring
  - **Exploring:**
    - Student-level communication patterns
    - Detecting at-risk behaviors
    - Alerting instructors to appropriate interventions



Collaboration?

- Contact: Dr. Bowen Hui, bowen.hui@ubc.ca


UBC
THE UNIVERSITY OF BRITISH COLUMBIA