Science Policy Research Report: Funding Team Science

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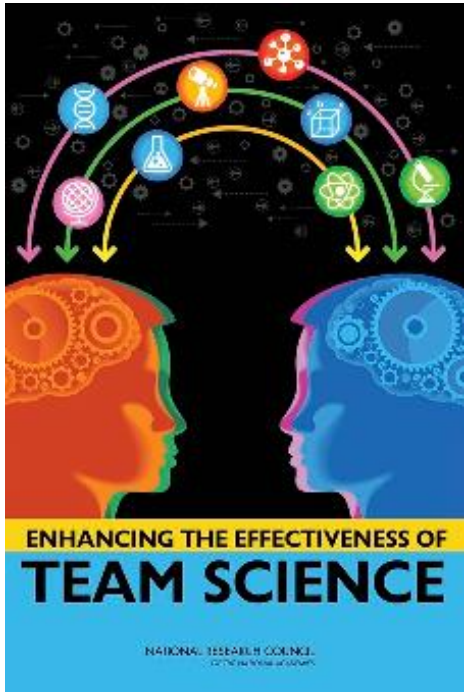
Team Science

- Collaboration of two or more scientists working interdependently towards a common research goal



"...while the increasing size of team-based research projects brings greater scientific expertise and more advanced instrumentation to a research question, it also increases the time required for communication and coordination of work (pg. 1)."

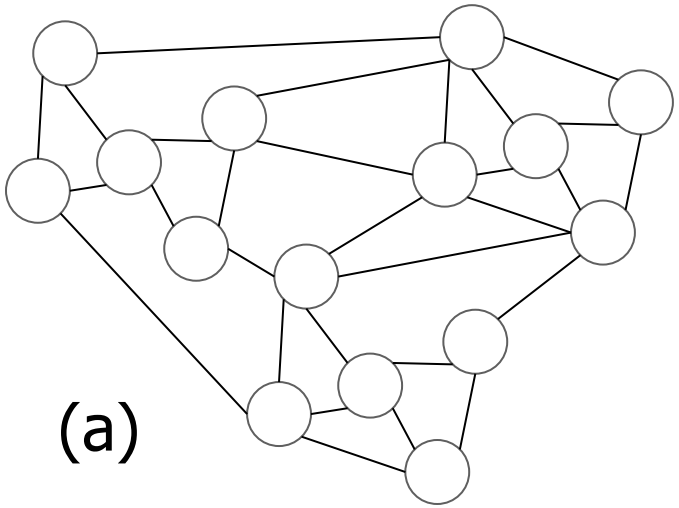
-- *Enhancing the Effectiveness of Team Science* (National Academies Press, 2015)

Role of Funding Agencies

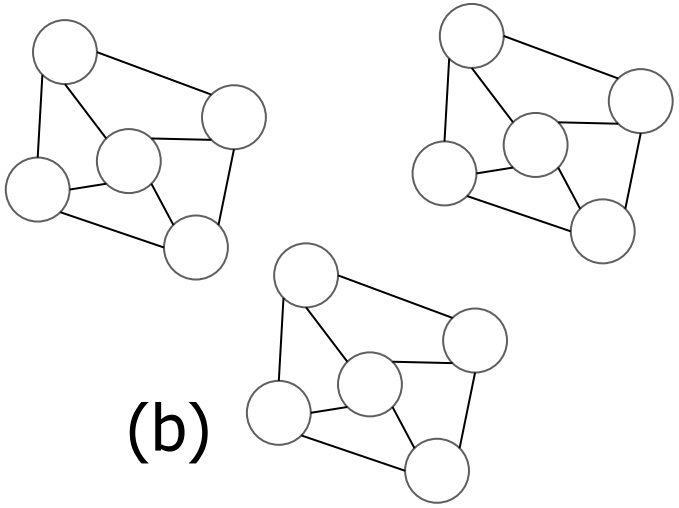
- Funding agencies (public and private) play a critical role in team science
- Program managers want to allocate resources to optimize complex problem solving, new research discoveries, and technological innovation
- Resource allocation includes determining which teams should get funded and how much funding they should get

Team Science Thought Question

- As a program manager, if you had a budget of US$1.5M, would you prefer to fund: (a) one larger team of 15 scientists ($1.5M for entire team) or (b) three smaller teams of five scientists ($500,000 for each team)? Why?



(a)



(b)

Note: the proposed science for the one 15-member team is identical to the proposed science across the three 5-member teams

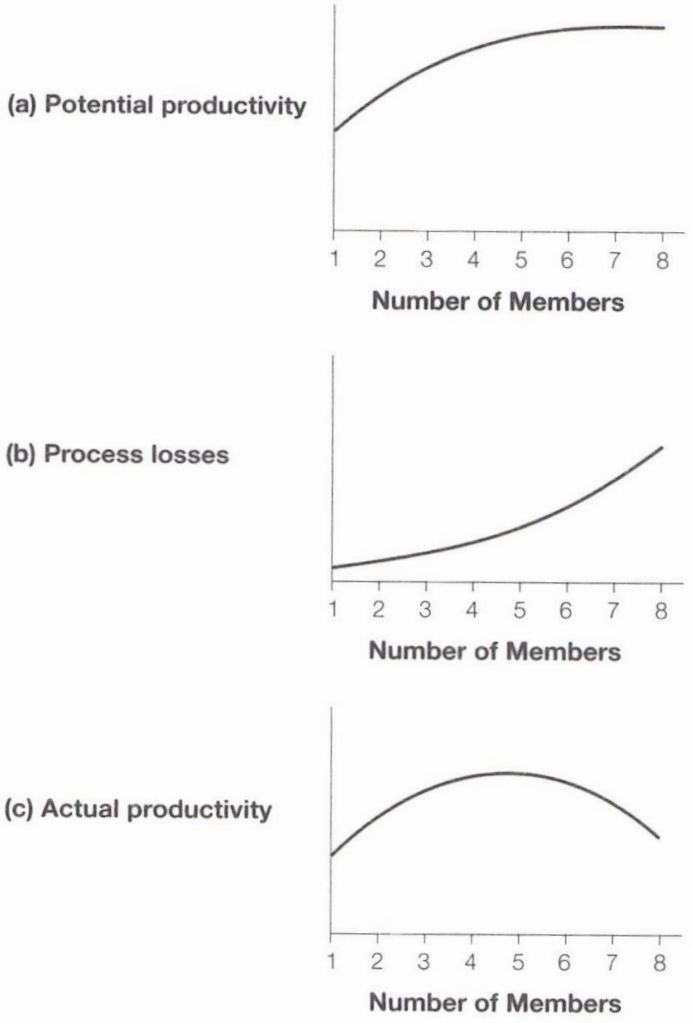
Evaluating Teams

- Team Process (i.e., how the team works together)
  - Satisfaction
  - Quality of Experience
  - Cohesion
  - Perceived Support
  - Rate of Participation
- Team Performance (i.e., what the team produces)
  - Research Papers
  - Journal Publications
  - Publication Impact
  - Patents Granted
  - Patent Impact

Trade-Offs of Team Size

- Process Losses
  - Motivation
    - (e.g., free-riding or social loafing)
  - Communication
    - (e.g., keeping up with all members)
  - Coordination
    - (e.g., integrating different tasks)
- Performance Gains
  - Effort
    - (e.g., more people working on task)
  - Expertise
    - (e.g., solve problems more quickly)
  - Division of Labor
    - (e.g., efficiently divide up tasks)

(Steiner, 1972)



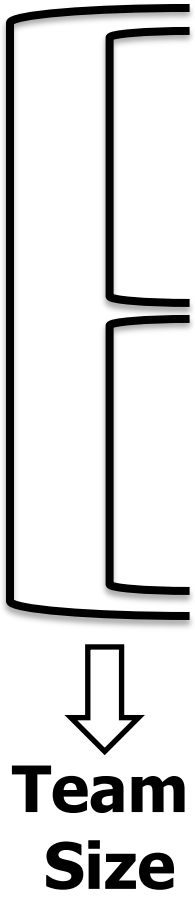
Literature Review on Team Size

(organizational behavior, psychology, sociology, economics, science studies, research policy, computer science, social science & medicine)

- Science Teams
  - Academic Research Teams
  - Corporate R&D Teams
  - Inventor Teams
- Non-Science Teams
  - Software Development Teams
  - Corporate Product Teams
  - Student Project Teams

- Excluded
  - Nominal Groups
  - Multi-team Systems
  - Research Centers
  - Scientific Networks
  - Online Communities
  - Crowdsourcing

Exploring Team Complexity



- Interdisciplinary
  - Disciplinary differences in language and norms about the research process need to be resolved
- Multi-Institutional
  - Geographic dispersion and cultural differences across institutions need to be resolved
- Interdependent Sub-Tasks
  - Task differences involving various resources, tools, applications, databases, experiments, and other elements of the science need to be resolved

Robust and Reliable Evidence

(a) strong causal inference (e.g., laboratory experiments and field experiments)

(b) moderate causal inference (e.g., longitudinal studies with appropriate controls)

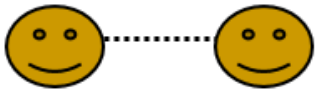
(c) weak causal inference (e.g., cross-sectional surveys and observational studies)

Threats to the Evidence (1)

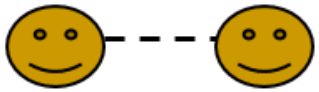
(1) Sample selection bias

Form team -> Apply for Grant -> Receive Grant -> Do Research -> Write Paper -> **[Publish Paper]**

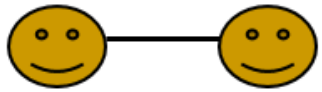
An illustration:



Did not work together
Did not publish together
58% of pairs on projects



Worked together
Did not publish together
18% of pairs on projects



Worked together
Published together
24% of pairs on projects

(Cummings & Kiesler, 2008)

Threats to the Evidence (2)

(2) Common data bias

e.g., Web of Science (Thomson Reuters) / Scopus (Elsevier) / Patent Database (USPTO)

Some implications:

- repeating multiple analyses on same data
- limited access (e.g., proprietary/commercial)
- missing data (e.g., non-English publications)
- author disambiguation (e.g., need machine learning)
- interoperability challenges (e.g., match with funding)

Empirical Evidence on Team Size

- Team Process *(Primarily Non-Science Teams)*
  - Satisfaction (e.g., Hackman & Vidmar, 1970)
  - Quality of Experience (e.g., Aube, Rousseau, & Tremblay, 2011)
  - Cohesion (e.g., Hoegl & Proserpio, 2004)
  - Perceived Support (e.g., Mueller, 2012)
  - Rate of Participation (e.g., Bray, Kerr, & Atkin, 1978)
- Team Performance *(Primarily Science Teams)*
  - Research Papers (e.g., Cummings, et al., 2013)
  - Journal Publications (e.g., Wuchty, Jones, & Uzzi, 2007)
  - Publication Impact (e.g., Lee, Walsh, & Wang, 2015)
  - Patents Granted (e.g., Bercovitz & Feldman, 2011)
  - Patent Impact (e.g., Breitzman & Thomas, 2015)

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- Team Performance *(Primarily Science Teams)*
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  - Publication Impact (e.g., Lee, Walsh, & Wang, 2015)
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A puzzle…

Team Complexity

- Team Process
  - Interdisciplinary
    (e.g., Lichtenstein et al., 1997)
  - Multi-Institutional
    (e.g., Cummings & Kiesler, 2005; 2007)
- Team Performance
  - Interdisciplinary
    (e.g., Leahey, Beckman, & Stanko, 2017)
  - Multi-Institutional
    (e.g., Jones, Wuchty, & Uzzi, 2008)

Team Complexity

* Diminishing marginal returns (Cummings et al., 2013)

- Team Process
  - Interdisciplinary (e.g., Lichtenstein et al., 1997)

(-)

  - Multi-Institutional (e.g., Cummings & Kiesler, 2005; 2007)

- Team Performance
  - Interdisciplinary (e.g., Leahey, Beckman, & Stanko, 2017)

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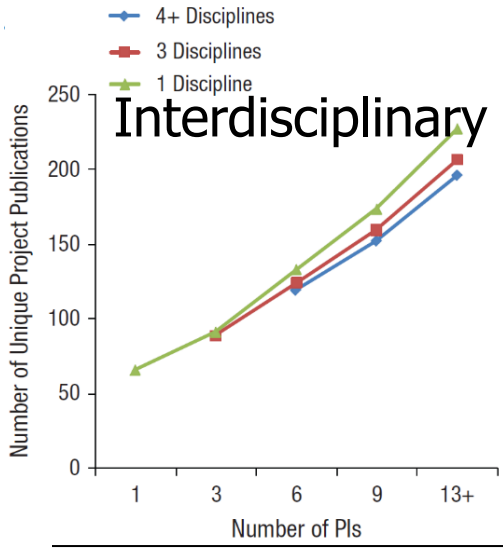

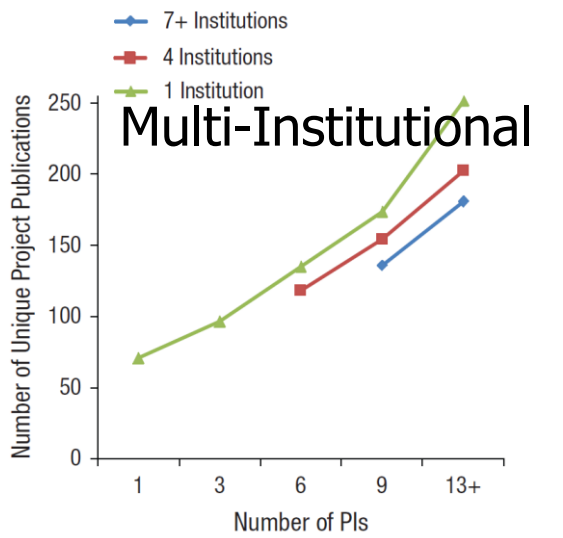

Policy Recommendations

(1) Add team size as a factor in the evaluation of proposals

- judge potential performance gains from each member on science team

(2) Add research integration as a factor in the evaluation of proposals with high team complexity

- judge potential process losses from each component (e.g., discipline, institution, or sub-task) on science team

Policy Implementation

Team Size

(1a) require PIs to justify team size in proposals

(1b) require reviewers to evaluate team size justification in proposals

Team Complexity

(2a) require PIs to include research integration plans in proposals when team complexity is high

(2b) require reviewers to evaluate research integration plans in proposals when team complexity is high

Future Directions

- Why is team size related to team performance in science teams?
  - Are science teams different in how they experience process losses? (e.g., fewer problems)
  - Do science teams benefit from unique performance gains? (e.g., economies of scale)
  - Is size a signal of science team quality?* (e.g., to grant panelists*, journal editors, and article readers)

* Conditional on proposal quality, funded proposals had significantly more principal investigators than unfunded proposals (Cummings & Kiesler, 2008)

Additional Research Questions

- How does team science participation influence individual productivity and impact (e.g., optimal mix of membership in large and small teams)?

- When is funding most useful for large and small science teams (e.g., early-stage research vs late-stage research; newly formed teams vs established teams)?

Thought Question Revisited

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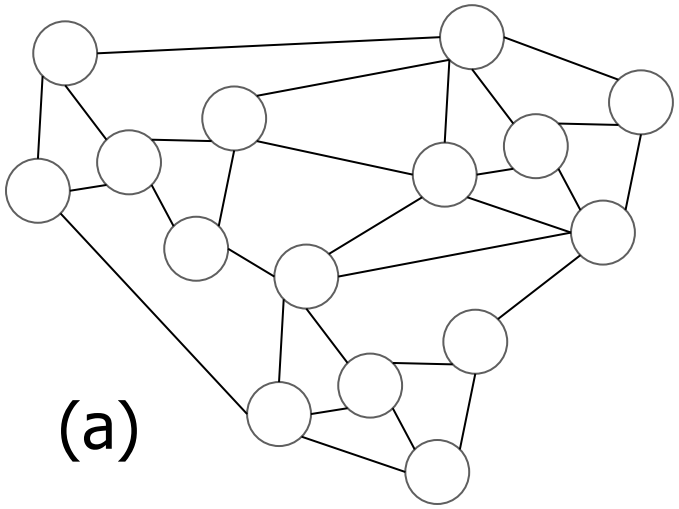
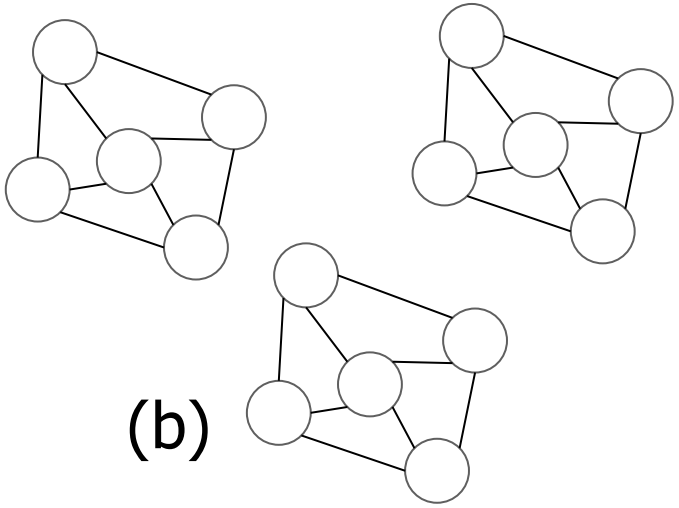


(a)



(b)

Low Complexity

High Complexity

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QUESTIONS?