# Board 431: Work in Progress: Fostering Team Science in an Engineering Education Research Team

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# WIP - Fostering Team Science in an Engineering Education Research Team


## Abstract

This poster displays results from a project supported by an NSF grant to enhance interdisciplinary collaboration in civil and environmental engineering education. In its second year, part of the project focused on improving team science competencies within the core research group. Key activities included workshops on collaborative writing and grant writing best practices. The team attended a Science of Team Science (SciTS) workshop to refine collaboration skills and responded to the Teaming Readiness Survey, which revealed strengths in valuing expertise but identified areas for improvement, such as role clarity and effective communication. In addition, the team responded to a Social Network Analysis Survey that showcased a growing network of research ties, indicating a robust collaborative environment, particularly among Principal Investigators. The preliminary results highlight a development in the team's effectiveness and psychological safety ratings, fostering trust and collaboration. The social network evolved from professional to social connections, with new members gradually integrating into the team. The research team concludes that focusing on collaborative skills and effective communication strengthens interdisciplinary collaboration in the changing scientific landscape.


## Introduction

In 2021, the co-authors of this poster were awarded an NSF Improving Undergraduate STEM Education (IUSE) grant to build the capacity of a faculty community of practice (CoP), positioning it to transform the way civil and environmental engineering education approaches diversity, equity, inclusion, and justice. A critical component of catalyzing effective change through Community of Practice (CoP) is building effective teaming competencies, first within the core research team, and then within the broader CoP. This poster displays preliminary findings on improving Team Science skills within the core research group.

The landscape of scientific research has evolved towards geographically dispersed and diverse teams collaborating on complex projects, necessitating effective team dynamics – this is true of our core research team as well as the larger CoP. The emergence of the science of Team Science (SciTS) reflects the growing recognition of the complexities inherent in collaborative research efforts [1]. SciTS is an interdisciplinary field focused on understanding the conditions that facilitate or hinder effective team-based research and its unique outcomes in productivity, innovation, and translation [2].

Team Science is a collaborative research approach that promotes openness, mutual respect, and shared responsibility among team members [3]. It encourages researchers to tap into a broader range of expertise, leading to more comprehensive and innovative solutions [4]. Effective communication and teamwork are essential components of Team Science, which contribute to developing a supportive and dynamic research environment. This collaborative approach is crucial for addressing the increasingly complex challenges of modern scientific research. Key features of Team Science include [3,4,5,6]:

- Interdisciplinary Collaboration: Team Science places a strong emphasis on fostering collaboration across diverse disciplines, bringing together researchers with varied expertise. This interdisciplinary approach is instrumental in cultivating a comprehensive understanding of intricate issues, leveraging the collective knowledge and skills of team members.
- Shared Goals and Objectives: Within Team Science, members collectively share common goals and objectives. These shared objectives typically are oriented towards addressing specific research questions or solving complex problems that demand a synergistic combination of diverse skills and knowledge. Alignment in goals is crucial for steering the team toward unified outcomes.
- Effective Communication: Clear and effective communication stands as a cornerstone in Team Science. Given the diverse backgrounds and expertise within the team, effective communication is paramount. Team members must articulate ideas, methodologies, and findings in a manner that is accessible and comprehensible to the entire team, facilitating seamless information exchange.
- Collaborative Decision-Making: Team Science involves a collaborative decision-making process where decisions are made collectively. This inclusive approach allows for the integration of diverse perspectives, ensuring that decisions are well-rounded and fostering cohesiveness as the team progresses towards its objectives.
- Conflict Resolution: Recognizing the diversity within teams, Team Science acknowledges that conflicts will arise. The approach to conflict resolution is constructive, emphasizing the importance of addressing conflicts in a manner that allows the team to navigate challenges effectively and maintain its collaborative momentum.
- Resource Sharing: In Team Science, members actively engage in resource sharing, encompassing the exchange of data, methodologies, and tools. This collaborative approach maximizes the efficiency of the research process, enabling team members to leverage shared resources for collective progress and success.

A study by Love et al. [4] delves into the characteristics of successful and unsuccessful collaborations, emphasizing the need for contributory, disciplinary, and interactional expertise in scientific breakthroughs. In another case study by Jiang et al. [5], complexity leadership theory was applied to understand and guide the change process in a cross-disciplinary group. The study showcases the importance of collaborative leadership, distributed decision-making, and contextual grounding for successful team science. These recent studies collectively highlight the evolving landscape of scientific collaboration, emphasizing the need for a transdisciplinary approach and effective team leadership.

Part of the NSF project explores our research team's journey in its pursuit of learning more about Team Science and applying tools to optimize interdisciplinary collaboration. The core research team collaborated with the Institute for Research in the Social Sciences (IRISS) at Colorado State University (CSU). The partnership with IRISS is intended to help the research team to a) build the capacity of our geographically dispersed Research Team by accelerating the team's integration to operate as a high-functioning team and b) explore whether Team Science might add value to a future grant proposal. In 2022, IRISS provided virtual training workshops for the Research Team on Team Science 101, Team Science Leadership and Shared Vision, and Team

Science Management and Communication [7]. In 2023, IRISS conducted a combined team readiness and social network analysis survey to collect measures of team readiness. Key activities included a workshop emphasizing collaborative writing and best practices for team ideation and grant writing. In addition, IRISS conducted two surveys focusing on team readiness and Social Network Analysis (SNA).

**Using SNA as an Assessment Tool**

SNA is a valuable method for understanding and evaluating the dynamics of Team Science. One of its main advantages is its ability to visualize and map collaborative relationships within a research team. Using graphical representations, SNA provides valuable insights into the network of connections, showing which individuals collaborate and how these interactions occur [3,6]. For instance, the results from the SNA survey can identify key team players by analyzing the network structure. It can pinpoint central figures who act as bridges, connecting different subgroups and facilitating effective communication and collaboration across the entire team.

Furthermore, quantitative analysis is one of the strengths of SNA, as it enables the measurement of collaboration patterns. Metrics such as the frequency and intensity of interactions between team members provide a quantitative understanding of collaboration [8]. This analysis can help identify areas of strength as well as opportunities for improvement. The density of the social network is a crucial metric assessed by SNA. Higher network density indicates a more interconnected and collaborative team. SNA can thus help identify areas where collaboration is thriving and areas where additional efforts may be needed to enhance connectivity [9]. Density is a measure of the possible number of connections in a network divided by the number of potential connections, which explains the overall structure of the network. Nodes in the diagrams were sized by in-degree. In-degree reports the number of ties that are going into a node. For example, if only one participant marked that they learned from Janice, then Janice will have an in-degree of one. However, if five other participants report that they learned from Jane, then Jane will have an in-degree of five. [10]

The effectiveness of a team can be measured through SNA by analyzing the quality and efficiency of collaborations. Teams with strong social ties and effective communication networks are more likely to achieve their goals, and SNA provides a method to quantify and evaluate this effectiveness [10]. For example, SNA can detect subgroups or cliques within a team. Recognizing these substructures is crucial for addressing potential challenges, ensuring that information and collaboration are not limited to specific clusters, and promoting inclusivity across the entire team [8]. Importantly, SNA is a dynamic methodology that can be applied iteratively over time. This allows teams to monitor changes in the social network structure, track the evolution of collaborations, and identify trends that may influence team dynamics, facilitating continuous improvement in collaborative efforts. The preliminary results presented in the poster will focus on data collected in 2023.

**Preliminary Results**

Participating in the Science of Team Science (SciTS) workshop was pivotal in the team's development. The insights gained from discussions on team formation, preferred practices, interdisciplinary challenges, and authorship agreements significantly influenced the team's approach and practices. As shown in Figure 1, the Teaming Readiness Survey provided a

nuanced understanding of the team's dynamics, revealing strengths and areas for improvement. The survey results indicated that team members valued each other's expertise and decision-making abilities, feeling confident, inspired, and respected within the team. However, areas such as role clarity and effective communication were identified as potential areas for improvement.

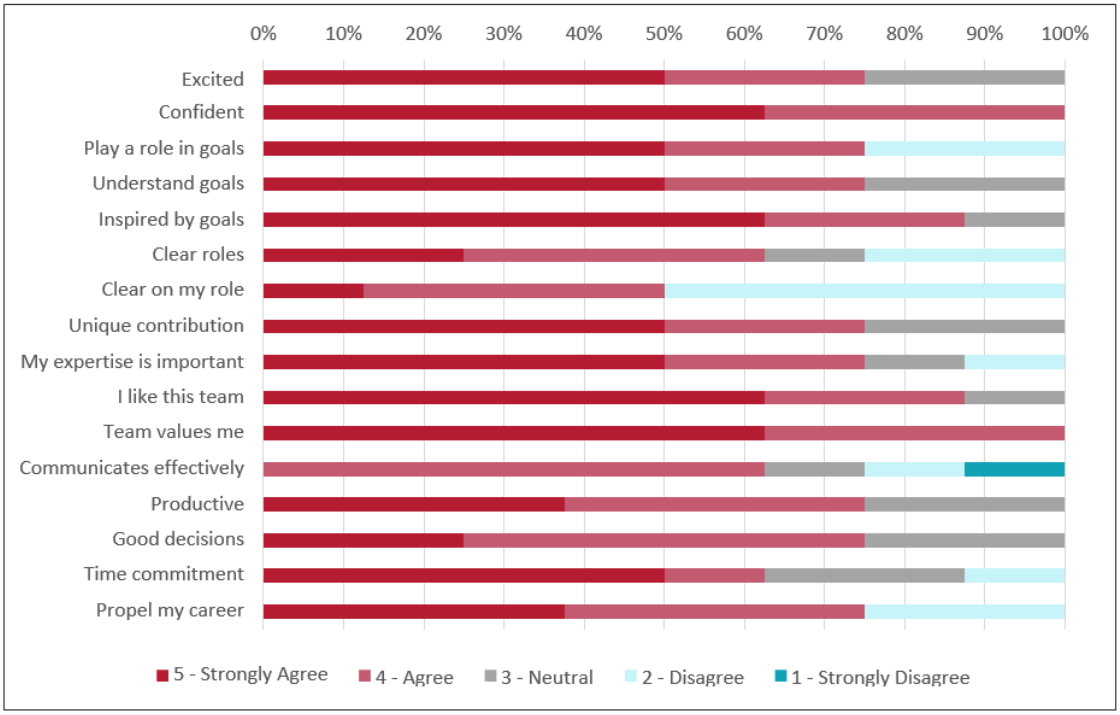


**Figure 1.** Responses to Team Readiness Survey.

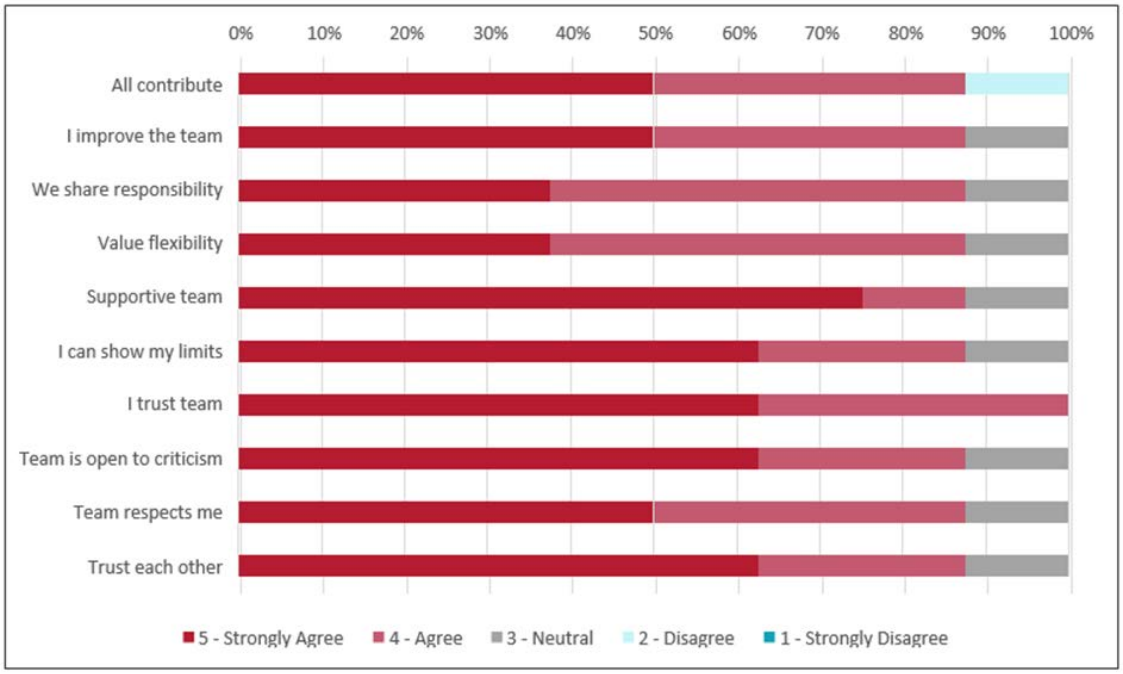


**Figure 2.** Collaborative Leadership and Psychological Safety

Figure 2 shows Likert-scale results regarding collaborative leadership and psychological safety. Most members consider the team supportive, which allows them to discuss limits, trust members, and be open to giving and listening to criticisms. The comments from 2023 indicate that team members really enjoy working together. For example, some of the team members' comments during the workshops related to feeling satisfied with being part of a team where they can learn from and with collaborators, having the potential to make a difference in the education of students, and the potential to further their careers.

IRISS also conducted an SNA Survey with the core team and their research assistants, close collaborators, and advisory board members. The team's social network analysis revealed that, on average, team members collaborated with 1.5 colleagues over the past year, indicating growing research ties compared with the previous year. Figures 3 to 8 show preliminary results of these networks. The network's density suggested a robust collaborative environment, especially among Principal Investigators.

While social interactions were divided into two larger groups, the network's expansion from four to sixteen members indicates an evolving collaborative landscape. In addition, participants in the research team exhibited high team effectiveness and psychological safety ratings, fostering an environment of trust and effective collaboration. The core members' strong professional and social relationships demonstrate the evolution from professional to social connections, especially among peers. The survey results suggested that new members gradually integrate into the team, particularly in learning and seeking advice.

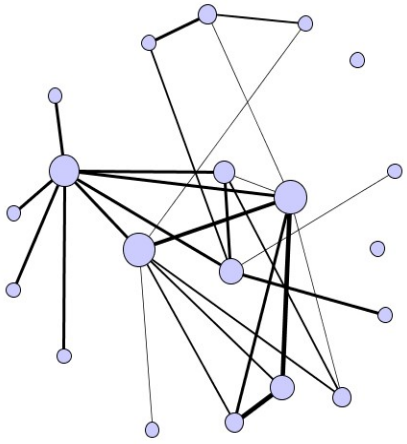

**Figure 3.** All research ties, Year 2
Average Degree = 1.50; Density = 0.08

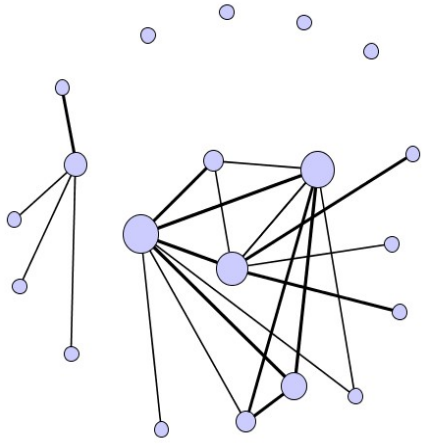

**Figure 4.** All social ties, Year 2
Average Degree = 1.30; Density = 0.07

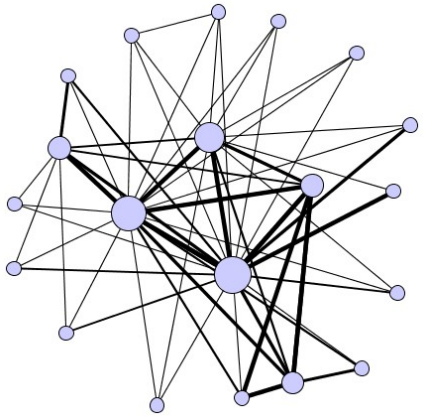

**Figure 5.** All help ties, Year 2
Average Degree = 3.45; Density = 0.18

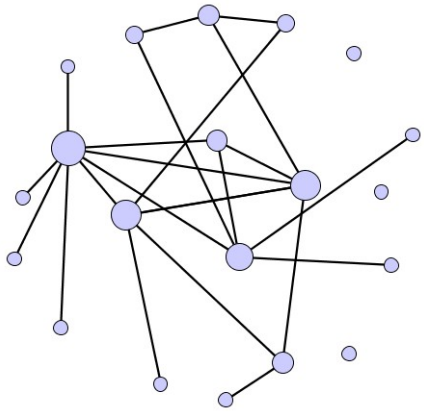

**Figure 6.** Talked about research ideas, Year 2
Average Degree = 1.15; Density = 0.06

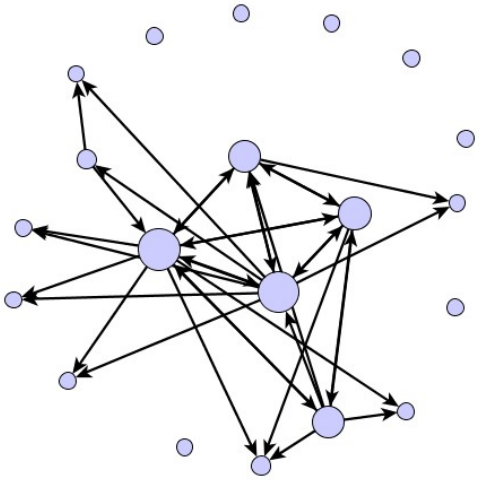

**Figure 7.** Seek assistance, Year 2
Average Degree = 1.75 Density = 0.09

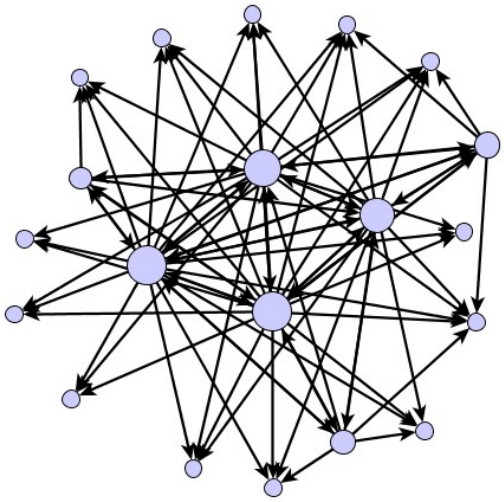

**Figure 8.** Learns from others, Year 2
Average Degree = 4.30 Density = 0.23

Reflecting on our workshop experiences, we gleaned valuable insights, including:

- Building a shared vocabulary: Our workshops facilitated the creation and sharing of a common vocabulary around key Team Science concepts, such as psychological safety, team readiness, and turn-taking-linking, commenting, passing.
- Piloting effective strategies: Embracing an experimental mindset, we collectively agreed to pilot several strategies, including "passing the conversation" or turn-taking, team charters, and engaging in writing sprints. This hands-on experimentation during the workshops provided us with valuable insights into the potential broader applications of these strategies.
- Practical application in low-stakes environments: Trying these strategies within the workshop setting allowed us to familiarize ourselves with their dynamics and functionality in a low-pressure environment. This not only increased our confidence in applying them but also encouraged us to employ these strategies autonomously during higher-stakes situations.

- Enhancing team integration: Strategies like intentional turn-taking and "passing the conversation" proved instrumental in swiftly integrating new team members. These approaches not only facilitated a smooth onboarding process but also contributed to fortifying the culture of respect that our team has diligently fostered.
- Visual representation of theories: The comparative analysis of mind maps and mental models offered a powerful method for exploring core project theories. This visual approach facilitated shared discussions on complex theories, promoting a deeper understanding among team members.
- Team writing strategies: Implementing team writing strategies and an equitable evaluation process became pivotal in distributing work and credit fairly, fostering collaboration and ensuring the team's collective success.
- Integration into broader processes: Recognizing the time required for integrating Team Science processes into the broader CoP, we gained insights into the gradual but impactful nature of this integration. This awareness informs our ongoing commitment to seamlessly aligning Team Science practices with the overarching goals of the community.

## Conclusion

The project's endeavors in Year 2 have provided valuable insights into the challenges and opportunities of Team Science in an interdisciplinary context. By enhancing collaborative skills, promoting role clarity, and facilitating effective communication, the team aims to strengthen the efforts further. As we reflect on these results, the team members collaborate well together with high team effectiveness and psychological safety ratings, as shown on the Likert-scale questions. The network has expanded from only four members to sixteen.

The core members have worked together for longer and have developed strong relationships for almost all professional and social indicators. Other members are slowly integrating, specifically on measures such as learning and seeking advice. Typically, teams develop professional relationships first, which evolve into social relationships later, especially among equals such as professor-professor and student-student relationships. This exploratory study offers essential lessons for researchers in the space of engineering education and research, emphasizing the importance of fostering effective interdisciplinary collaboration in a rapidly changing scientific landscape.

## Acknowledgements

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