

# Studying Faculty Communities of Practice Through Social Network Analysis

Shufeng Ma

Department of Educational Psychology  
University of Illinois at Urbana-Champaign  
Urbana, IL 61801  
sma10@illinois.edu

Matthew West

Department of Mechanical Science & Engineering  
University of Illinois at Urbana-Champaign  
Urbana, IL 61801  
mwest@illinois.edu

Geoffrey L. Herman

Illinois Foundry for Innovation in Engineering Education  
University of Illinois at Urbana-Champaign  
Urbana, IL 61801  
glherman@illinois.edu

Jonathan Tomkin

Department of Geology  
University of Illinois at Urbana-Champaign  
Urbana, IL 61801  
tomkin@illinois.edu

Jose Mestre

Department of Physics  
University of Illinois at Urbana-Champaign  
Urbana, IL 61801  
mestre@illinois.edu

**Abstract**—Creating systemic change in undergraduate engineering and STEM education is difficult to achieve and just as difficult to study. It has been proposed that organizational learning and change theories can be coupled with social network analysis to achieve both of these goals. In this paper, we describe an institutional change effort designed around principles from Communities of Practice. We then present the design of a social analysis network study that we are executing to study and analyze whether this change effort has been successful in achieving its goals. We present some preliminary data to demonstrate the promise of this approach for executing and studying institutional change in engineering education and STEM education more broadly.

**Keywords**—*institutional change; research-based instructional strategies; evidence-based instructional practices; communities of practice; social network analysis*

## I. INTRODUCTION

Education research often remains inert, failing to cross the research-to-practice divide [1-3]. Change agents in engineering education have specifically become increasingly concerned about how to promote the sustained use of Evidence-Based Instructional Practices (EBIP) [4, 5]. This paper presents the first stage of a longitudinal study of an institutional change effort focused on promoting the sustained use of EBIP. While there are many components to this study, this paper describes our methods for using Social Network Analysis (SNA) to explore how relational networks and patterns influence teaching behaviors [6].

SNA takes the adage “it’s not what you know, it’s who you know” to its extreme by arguing that “who you know determines what you can know [6].” SNA reveals that an individual’s performance and their access to information and use of practices can be predicted by the characteristics of their social network and the organizational structure around them [6, 7]. Given the importance of social networks for determining behaviors, it can be hypothesized that changing the social network structures around faculty could potentially provide a means for sustainably changing their teaching practices. To disrupt these social network, we are organizing faculty into Communities of Practice (CoPs) [8] that are focused on improving instruction in large enrollment engineering and STEM courses. These CoPs provide a potential context for creating supportive, information-rich networks and studying how these social network structures encourage and engage faculty in the adoption and sustained use of EBIP.

At the University of Illinois at Urbana-Champaign, we have created two such CoP-centric programs to create institutional change in instructional practices in engineering and STEM more broadly. These programs are distinct, but are connected philosophically. The first program, Strategic Instructional Innovations Program (SIIP), is based in the College of Engineering and was originally conceived as a mechanism to improve instruction in large-enrollment (>200 students per semester) courses across the college. The second program funded by the NSF WIDER program [DUE 1347722] is a spin-off of SIIP that is STEM-inclusive, marshaling faculty from multiple colleges. These programs aimed to create a supportive environment that would enable CoPs to emergently

adopt EBIP. In both programs, faculty are organized into CoPs that meet regularly (i.e., weekly or every other week) to decide how to reform a target course or sequence of courses. Mentors drawn from a network of tenured professors are embedded into each CoP to accelerate the learning of the CoP and to spread knowledge of reforms between CoPs.

Detailed descriptions of how SIIP/WIDER are structured and run can be found in previous publications [9, 10]. For the purpose of this paper, it is sufficient to understand that both SIIP/WIDER organize faculty into course-centric CoPs, these CoPs have mentors, and that these mentors meet to discuss how to mentor their CoPs. The goal of this initial study is to document the social interactions created by this CoP and mentor structure and to study how the social network structures connect to sustained changes in teaching practices.

Specifically, we describe our efforts to document and study the social network structures that undergird functional and dysfunctional faculty CoPs (i.e., those CoPs that sustainably use EBIP versus those that do not, respectively). Critically, since we are focusing on simply describing the social network structures, we do not discuss the theoretical or practical considerations for CoPs should optimally operate. Rather, we focus on describing our collection and analysis of social network data as an alternate framework for exploring the effect of organizing faculty into CoPs. We conclude by presenting some preliminary findings and a discussion of future work.

## II. BACKGROUND

Calls for change in higher education are abundant, yet change is elusive [11]. Research in engineering education has generally focused on the barriers that prevent change [12-15]. While there are many barriers, connecting organizational change theories with social network analysis can reveal avenues to overcome these barriers [6, 8, 16-19]. Successful change initiatives must disrupt organizational norms and existing social networks [20, 21] and then use processes that support senses of justice or trust [17, 18] to create new shared values and organizational learning [6, 8], and create new social networks that support and institutionalize change [6, 16].

Disruptions can be created by external pressures that drive the need for change within an organization [16, 21] or from reorganizing personnel into new working groups [20]. These disruptions must require new operational norms, creating new interdependencies in the organization. For SIIP/WIDER, escalating enrollments created pressure that motivated faculty to change how they teach. By organizing faculty into CoPs, we disrupted their social norms around individualized/independent teaching to create collaboration and interdependencies.

While social network analysis has been used in a variety of contexts, only recently have research begun applying these methods to study change in education [6]. A majority of these research studies have focused on elementary and secondary educational settings, revealing how social networks can improve students' outcomes or increase the use of desired teaching methods among instructors [22-24]. These studies have generally found that increased social connections are predictive of the use of EBIP [23]. Elementary school teachers who productively changed their teaching methods had more

connections with experienced and novice teachers than teachers who did not productively change their teaching methods [24]. Neal, et al. [22] more specifically found that teachers were more likely to change their teaching practices if they saw a peer using a teaching method than if they saw a mentor using the same technique. They concluded that the decision-making of peers with the same mentor created a greater sense of confidence and value (i.e., "if my peer can do it, so can I") than other social connections [22].

Although SNA has provided insights into K-12 teaching practices, it has rarely been used to study changes in faculty teaching practices in undergraduate settings [7, 18]. For example, Quardokus and Henderson [7] have developed sociometric surveys to capture and document faculty teaching networks, but have not yet published studies that study how those networks create change. Middleton, et al. [25] have begun investigating the effect of social networks on faculty teaching practices during lectures, finding correlations between network density and increased use of EBIP during lectures. To our knowledge, no research studies have studied the formation of faculty CoPs through social network analysis. To fill this gap, we plan to investigate two research questions.

- 1) What social network structures are predictive of the formation and effective functioning of Communities of Practice of faculty?
- 2) What role do SIIP/WIDER administrators and departmental administrators play in the creation and formation of faculty CoPs?

## III. METHODS

Both SIIP/WIDER conduct annual project evaluations of the CoPs using a common rubric. As a grant program, SIIP requires faculty to work in teams of at least three faculty members so that a CoP can form around the proposed innovation or reform. Continued funding for these CoPs is contingent on their annual evaluations, particularly their ability to develop collaboratively owned reforms. WIDER, unlike SIIP, is more inclusive of all STEM disciplines. The emphasis in WIDER is on formalizing faculty CoPs rather than on providing funding to create change. Consequently, WIDER CoPs receive substantially less funding than SIIP CoPs for their efforts.

### A. Measures

We will first use three metrics to explore our research questions: a sociometric survey, documented funding levels of the CoPs, and project evaluations. Future work will focus on using course syllabi and assignments to further validate the use of EBIP by CoPs and the spread of EBIP across CoPs.

#### 1) Sociometric survey

The sociometric survey was derived from the survey created by Quardokus and Henderson [26]. Their survey was designed to identify the teaching networks of faculty within a department by asking faculty to identify with whom they talked about teaching and the frequency of their interactions. We adapted the survey so that all SIIP/WIDER participants would indicate the frequency of their interactions with all other SIIP/WIDER participants. Participants were ordered based on

their department and then by alphabetical order. SIIP/WIDER span 18 departments and 142 faculty. Because the structure of our intervention was to create CoPs, we decided to distinguish between conversations and collaboration, as collaboration is more indicative of deeper involvement whereas talking can readily occur outside a CoP. Consequently, we added an additional category for *type of interactions* (i.e., talking vs. collaboration) and provided more definitions of teaching, talking, and collaboration than did Quardokus and Henderson [7]. An example row of the survey is presented in Fig. 2.

2) *Funding levels*

The funding level of each CoP came from SIIP/WIDER budget documents. Funding levels reflect the amount of money available to each CoP and not how much each CoP actually spent. Funding levels ranged widely from \$4K to \$150K.

3) *Project Evaluations*

A common project evaluation rubric was developed for SIIP/WIDER that went into use during the 2013-2014 school year. This rubric was developed iteratively by members of the leadership teams of SIIP and WIDER to capture what they believed to be the characteristics of functional innovation CoPs. For SIIP, each project was evaluated using the rubric by at least three members of the leadership team to ensure fairness of decision making and ratings. If a member of the leadership team was part of a CoP, they were required to leave the room during evaluations to promote honest deliberation and ratings. For SIIP, these evaluations were used to determine which newly-proposed projects would be funded and which on-going projects would continue to be funded. For WIDER, the rubric was used primarily as formative feedback for the leadership team to help them identify the functional and dysfunctional CoPs and to identify strategies to help CoPs succeed.

The rubric rated each team along five dimensions: administrative support, collaborative development and ownership, faculty outcomes, student outcomes, and sustainability/trajectory. A rating of Outstanding, Commendable, Satisfactory, Improvement Required, or Not Acceptable was given to each category. These individual ratings culminated in an overall rating that classified project COP as functional or dysfunctional. Ultimately, functional CoPs demonstrate a sustained use of EBIP across instructors or semesters whereas dysfunctional CoPs do not.

4) *Data Collection*

Surveys were collected both in person using paper and pencil surveys (26 surveys collected) as well as using an online version of the survey (76 surveys collected). In total, 102 responses were collected (response rate = 72%). Two responses were not included in the data analysis because one respondent left the university and another respondent submitted an incomplete survey. Therefore, the final dataset includes 100 participants, among which 72% are male faculty and 28% are

female faculty. Sixty-five percent of the participants are Caucasian, 15% are Asian, and the rest are from other ethnic groups or unwilling to provide the information. The dataset includes 32% full professors, 23% associate professors, 22% assistant professors, and 23% non-tenure track faculty. Eleven serve as project leaders of which seven were also participants in CoPs. Seven people work as departmental or college administrators and were not members of CoPs. The remaining participants were non-administrative faculty in CoPs.

Responses spanned 15 departments (number of faculty from each department is indicated in parenthesis: agricultural and biological engineering (1), bioengineering (6), civil and environmental engineering (12), chemistry (4), computational science and engineering (1), computer science (9), electrical and computer engineering (16), geology (5), industrial and enterprise engineering (5), integrative biology (4), materials science and engineering (8), mechanical science and engineering (16), molecular and cellular biology (3), physics (4). Other participants were from the College of Education (2) or the College of Engineering without a department (4).

5) *Measures of social network connections*

In a social network analysis, centrality indices are commonly used to identify the most important node in the network. The importance of a node can be reflected by the number of connections one node has with its adjacent nodes (degree centrality), how close that node is apart from every other node (closeness centrality), or how much control one node has over the interaction between an unconnected pair of nodes (betweenness centrality) [27].

As the three centrality indices measure different aspects of a person’s status, prestige, or popularity, we will use all three indices to gauge a faculty member’s influence in maintaining a functional community of practice. All the centrality scores are normalized to 1 for data analyses.

6) *Visualization of the collaboration network*

The visualization of the collaboration network is provided to show the promise of this approach. The network visualization in Fig. 3 was generated algorithmically using the ForceAtlas2 layout with Lin-Log model [28]. Administrators are excluded from this collaboration network. Each faculty member is represented by a circle: The size of a circle is determined by an individual’s degree centrality and the color indicates that faculty member’s department. Larger circles indicate that a node is more connected. Circles with a solid black outline are SIIP/WIDER leaders. A line between two circles indicates that two faculty members actively collaborated on teaching.

Dashed circles were added manually and represent the 22 SIIP/WIDER CoPs. The fill color (light blue or light orange) of the dashed circles indicate whether a CoP was rated as

During the 2013-2014 and 2014-2015 school years, I talked and/or collaborated with this person about teaching-related activities with the following frequencies				
Name	Never interacted about teaching	Occasionally talked about teaching	Frequently talked about teaching	Actively Collaborated on teaching
Jane Doe				X

Fig. 2. Example row of the sociometric survey

functional or dysfunctional, respectively. There are a few cases in which an individual is far from their assigned community—a dashed line with an arrow is used to indicate where that faculty member belongs. This visualization shows that social network analysis can readily detect the formation of CoPs even detecting cross-departmental CoPs and multiple CoPs within a department. For example, the blue circles at the top of the diagram are all from the same department. The faculty from this department clustered into three CoPs: one intra-departmental functional CoP (top), one intra-departmental dysfunctional CoP (below the latter), and one inter-departmental functional CoP (below and to the right).

The density of network connections suggest that network structures may indicate whether a CoP is functional. Dysfunctional CoPs had fewer collaborations within their CoPs (average degree = 4) than functional CoPs (average degree = 12). Functional communities also had more direct collaborations more with other functional communities ( $N = 10$ ) while dysfunctional communities seldom collaborated with each other ( $N = 4$ ). CoP mentors are the most connected members of the network (average degree = 15).

Notably, the CoP mentors also play a critical role in bridging the diverse CoPs. Over 70% of collaborative

connections (100 of 142) that go outside an individual CoP are to CoP mentors. Without the CoP mentors, it is unlikely that information and practices would spread between the CoPs.

#### IV. FUTURE WORK

Building from these preliminary visualizations, we will use multi-level regression analysis to explore which individual factors (funding level, degree centrality, closeness centrality, betweenness centrality, academic rank, gender, etc.) predict the formation of functional CoPs. This analysis will enable us to move from qualitative observations of the network toward statistical inference on how these CoPs function. Our analysis will also specifically explore whether talking and collaboration result in different network characteristics and what role project leaders plan in sustaining the network.

#### REFERENCES

- [1] C. Henderson, A. Beach, and N. Finkelstein, "Facilitating change in undergraduate STEM instructional practices: An analytic review of the literature," *Journal of Research in Science Teaching*, vol. 48, pp. 952-984, 2011.
- [2] T. Moldonado, "Engineering Education & Centers: An integrative

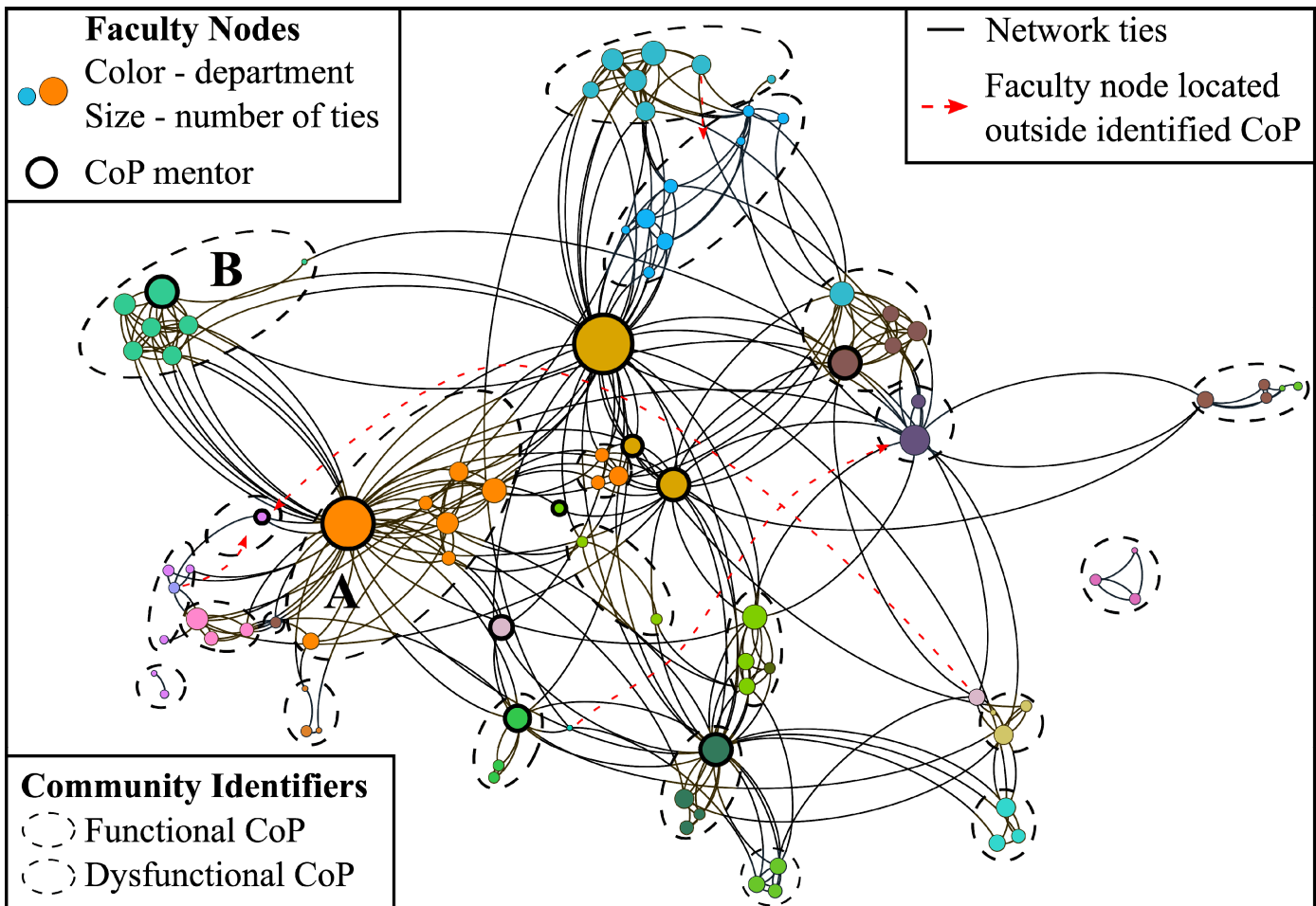


Fig. 3. The collaboration network of SIIP/WIDER. Participants are arranged by their information centrality in the network. Ovals indicate the actual CoPs. The color of the ovals indicate whether a CoP was functional or dysfunctional as determined by the project evaluations. The color of nodes indicate department. Nodes with black rings indicate SIIP/WIDER administrators.

- mission," ed. NSF ENG Advisory Committee Meeting, 2011.
- [3] R. Spalter-Roth, N. Fortenberry, and B. Lovitts, *The Acceptance and Diffusion of Innovation: A Cross-Disciplinary Approach to Instructional and Curricular Change in Engineering*. Washington DC: American Sociological Association, 2011.
  - [4] M. Borrego, S. Cutler, M. Prince, C. Henderson, and J. E. Froyd, "Fidelity of implementation of Research-Based Instructional Strategies (RBIS) in Engineering Science Courses," *Journal of Engineering Education*, vol. 102, pp. 394-425, 2013.
  - [5] M. Borrego and C. Henderson, "Increasing the use of evidence-based teaching in STEM higher education: A comparison of eight change strategies," *Journal of Engineering Education*, vol. 103, pp. 220-252, 2014.
  - [6] A. J. Daly, *Social Network Theory and Educational Change*. Cambridge, MA: Harvard Education Press, 2010.
  - [7] K. Quardokus and C. Henderson, "Promoting instructional change: Using social network analysis to understand the informal structure of academic departments," *Higher Education*, vol. 70, pp. 315-335, 2015.
  - [8] E. Wenger, *Communities of Practice: Learning, Meaning, and Identity*. Cambridge: Cambridge University Press, 1998.
  - [9] G. L. Herman, L. Hahn, and M. West, "Coordinating college-wide instructional change through faculty communities," in *Proceedings of the 2015 International Mechanical Engineering Congress & Exposition*, Houston, TX, 2015, pp. IMECE2015-51549.
  - [10] G. L. Herman, I. B. Mena, J. C. Greene, M. West, J. Tomkin, and J. Mestre, "Creating institution-level change in instructional practices through faculty communities of practice," in *2015 American Society for Engineering Education Annual Conference and Exposition*, Seattle, WA, 2015, pp. 26.419.1-26.419.13.
  - [11] A. Kezar, "Change in higher education: Not enough, or too much?," *Change: The Magazine of Higher Learning*, vol. 74, pp. 18-23, 2009.
  - [12] D. Allen and K. Tanner, "Infusing active learning into the large-enrollment biology class: Seven strategies, from the simple to complex," *Cell Biology Education*, vol. 4, pp. 262-268, 2005.
  - [13] L. Barker, C. L. Hovey, and J. Gruning, "What influences CS faculty to adopt teaching practices?," presented at the ACM SIGCSE 2015, Kansas City, MO, 2015.
  - [14] S. Brownell and K. Tanner, "Barriers to faculty pedagogical change: Lack of training, time, incentives, and tensions with professional identity," *CBE-Life Sciences Education*, vol. 11, pp. 339-346, 2012.
  - [15] C. J. Finelli, K. M. Richardson, and S. Daly, "Factors that influence faculty motivation of effective teaching practices in engineering," presented at the *Proceedings of the 120th American Society for Engineering Education Annual Conference & Exposition*, Atlanta, GA, 2013.
  - [16] M. Beer, *Leading Change*. Boston, MA: Harvard Business School Teaching Note, 2007.
  - [17] J. A. Colquitt, B. A. Scott, J. B. Rodell, D. M. Long, C. P. Zapata, D. E. Conlon, et al., "Justice at the millennium, a decade later: a meta-analytic test of social exchange and affect-based perspectives," *Journal of Applied Psychology*, vol. 98, pp. 199-237, 2013.
  - [18] A. Kezar, "Higher education change and social networks: A review of research," *The Journal of Higher Education*, vol. 85, pp. 91-125, 2014.
  - [19] A. Kezar, *How Colleges Change: Understanding, Leading, and Enacting Change*. New York: Routledge, Taylor & Francis Group, 2014.
  - [20] M. Uhl-Bien, R. Marion, and B. McKelvey, "Complexity leadership theory: shifting leadership from the industrial age to the knowledge era," *The Leadership Quarterly*, vol. 18, pp. 298-318, 2007.
  - [21] J. P. Kotter, *Leading Change*. Cambridge, MA: Harvard Business Review Press, 2012.
  - [22] J. W. Neal, Z. P. Neal, M. S. Atkins, D. B. Henry, and S. L. Frazier, "Channels of change: Contrasting network mechanisms in the use of interventions," *American Journal of Community Psychology*, vol. 47, pp. 277-286, 2011.
  - [23] E. Judson and A. E. Lawson, "What is the role of constructivist teachers within faculty communication networks?," *Journal of Research in Science Teaching*, vol. 44, pp. 490-505, 2007.
  - [24] N. Penuel, M. Riel, A. Krause, and K. Frank, "Analyzing teachers' professional interactions in a school as social capital: A social network approach," *Teachers College Record*, vol. 111, pp. 124-163, 2009.
  - [25] J. A. Middleton, S. Krause, K. Beeley, E. Judson, J. Ernzen, and R. Culbertson, "Examining the relationship between faculty teaching practice and interconnectivity in a social network," presented at the 2015 ASEE/IEEE Frontiers in Education Conference, El Paso, TX, 2015.
  - [26] K. Quardokus and C. Henderson, "Using department-level social networks to inform instructional change initiatives," in *Proceedings of the NARST 2014 Annual Meeting*, Pittsburgh, PA, 2014.
  - [27] L. C. Freeman, "Centrality in social networks: Conceptual clarification," *Social Networks*, vol. 1, pp. 215-239, 1979.
  - [28] A. Noack, "Energy models for graph clustering," *Journal of Graph Algorithms and Applications*, vol. 11, pp. 453-480, 2007.