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Using social network analysis to develop relational expertise for an instructional change initiative

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Abstract

Background: Change leaders (faculty, administrators, and/or external stakeholders) need to develop *relational expertise*, recognizing the perspectives of others, to enable emergent, systemic change. We describe how change leaders of a grant-funded instructional change initiative developed relational expertise by analyzing faculty relationships and social subgroups to identify *who* was involved in discussions about teaching and learning and *what* specific topics were discussed.

Results: Faculty discussions focused on daily classroom needs. Faculty who were in different departments or schools were mostly disconnected from each other, and faculty within these units often had subdivisions among them.

Conclusions: Faculty lacked opportunities to discuss education, specifically, systems-level perspectives. The change leaders created organizational structures to catalyze communities, including an action research fellowship program, to support faculty in education discussions.

Keywords: Relational expertise, Instruction, Social network analysis, Leadership, Department, Change

Introduction

A central goal of Science, Technology, Engineering, and Mathematics (STEM) educators is to prepare students to be productive in the STEM workforce and to make informed decisions as citizens. STEM instruction needs to improve if educators are to prepare graduates to contribute to the sociotechnical needs of twenty-first century society, such as advancing health care, preserving the environment, and informing political decisions (Committee on Prospering in the Global Economy of the 21st Century, 2007; Holdren, Marrett, & Suresh, 2013; Singer, Nielsen, & Schweingruber, 2012). Change initiatives in education attempt to transform learning systems, educational structures, or processes (e.g., classroom practices) to improve the preparation of students (Henderson, Beach, & Finkelstein, 2011). These initiatives are led by faculty members (tenure-track or fixed-term) from the classroom or administrators who create change from enacting policy or encouraging practices.

The context for this study is the design of a STEM education change initiative within a single university. This article has two parts. First, we use analysis of social relationships to understand the institutional context for change by identifying *what* educational interests were discussed within disciplinary units and *who* were key players in the discussion. Second, we describe how the leaders of the change initiative used this analysis of the social relations to design tangible activities. While such activity design entails contextual factors beyond the scope of the first part of the article, the second part serves to provide an example of how change leaders can use the understanding described in part one to take action. In the next section, we expand upon the motivation for this study.

Motivation: considering institutional context

The leaders of this change initiative elicited collaboration across seven disciplinary STEM units to be cognizant of contextual influence on change and to create large-scale change. (In this study, we use disciplinary units to encompass departments or schools at the institution where degree-granting and tenure and

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promotion decisions are made. We use change leaders to refer to the designers and leaders of the change initiative.) Collaborators included STEM instructional faculty, education researchers, and administrative leaders. Collaboration with experts from diverse disciplines (e.g., mathematics, biology, engineering, education) and roles within the institution (e.g., administrators, tenure-track faculty, fixed term faculty) created advantages and challenges for the initiative. The assumed advantage of these experts was the diversity of knowledge that each expert contributed to the project (Edwards, 2005) and the assumed advantage of collaboration throughout the university was the opportunity to enable large-scale change.

However, the change leaders were concerned that the contexts of the disciplinary units could pose a challenge to the change initiative. Specifically, collaborators from different units may not have shared interests regarding change to instructional practices and this misalignment of interests could lead to disengagement in change activities (Bouwma-Gearhart, Perry, & Presley, 2014; Edwards, 2012). Institutional contexts (for example, teaching climate and/or current instructional practices) may inhibit the realization of the change leaders' goals (Kezar, 2005). In addition, the influence of context on change may be localized within disciplinary units (Trowler, Fanghanel, & Wareham, 2005). For example, teaching practices that may be popular within a disciplinary unit might not align with research-based evidence (Bradforth et al., 2015). The change leaders recognized that these contextual realities and the interests of the collaborators should inform the planning of improvement activities (Finelli, Daly, & Richardson, 2014; Kezar, Carducci, & Contreras-McGavin, 2006).

Through this study, the change leaders aimed to build *relational expertise* to inform the design of tangible activities for instructional improvement. Relational expertise is the ability to recognize group values that are created and negotiated through social connections and mediate cooperation across value boundaries (Edwards, 2012; Pittinsky & Carolan, 2008). Specifically, this expertise would enable development of instructional faculty communities of practice (Wenger, 1998) focused on implementing evidence-based instructional practices (EBIPs) across disciplinary units. The exploration of the context within disciplinary units through social connections was guided by two research questions:

1. What topics of teaching and learning are most important to faculty in disciplinary units as demonstrated by their reported frequency of discussion by unit members?
2. Who is involved in discussions regarding teaching and learning as measured by the social connections that are identified? What subgroups do they form?

Setting: change initiative

This change initiative took place at a Land Grant, Carnegie Research 1, and doctorate-granting university in the USA. The goal of the change initiative was to improve instruction of large-enrollment, lower-division STEM courses across multiple STEM disciplinary units through implementation of two broad types of EBIPs—(1) interactive engagement with frequent formative feedback (Chi & Wylie, 2014; Freeman et al., 2014, p. 2) and formal cooperative learning (Johnson & Johnson, 1987; Smith, Sheppard, Johnson, & Johnson, 2005). The targeted courses for change were offered by seven STEM units: three science units (biology, chemistry, and physics), three engineering units (chemical engineering, civil engineering, and mechanical engineering), and mathematics. Students who were enrolled in courses that incorporated EBIPs were expected to develop well-connected conceptual knowledge structures and non-linear, iterative problem-solving abilities (Koretsky, Bouwma-Gearhart, Brown, Dick, Brubaker-Cole, & Sitomer, 2015).

The change leaders consisted of faculty members from the STEM units, faculty from the college of education, members of the campus's STEM education research center, and institution administration (e.g., vice provost). The change leaders planned to use communities of practice (Wenger, 1998) of educators to facilitate collaborative learning among faculty members about EBIPs implementation from within and across disciplinary units. The change leaders were aware of individual innovators and preexisting communities focused on improving STEM education acting largely within their local units' environments who could benefit from participation in these communities. The change leaders set out to support and encourage participation in preexisting communities and to build communities specifically connecting innovators developing and implementing EBIPs in STEM courses.

Figure 1 presents a schematic representation of the expected impact of the change initiative. In the image on the left of Fig. 1, the state of the seven units are represented at the start of the initiative. Each unit has a core set of innovators but activity is mostly isolated with only a few collaborations across units (represented by arrows). The image on the right of Fig. 1 shows the expected outcomes of change; the units are overlapping with more intersecting communities of practice focused on improving STEM education. The work of the core innovators is also depicted as diffusing throughout each unit. By catalyzing communities, the change leaders sought to cultivate an environment that encouraged emergent change; that is, change that is developed by participants such that it addresses the participants' needs and the goals of the initiative (Austin, 2011; Henderson et al., 2011).

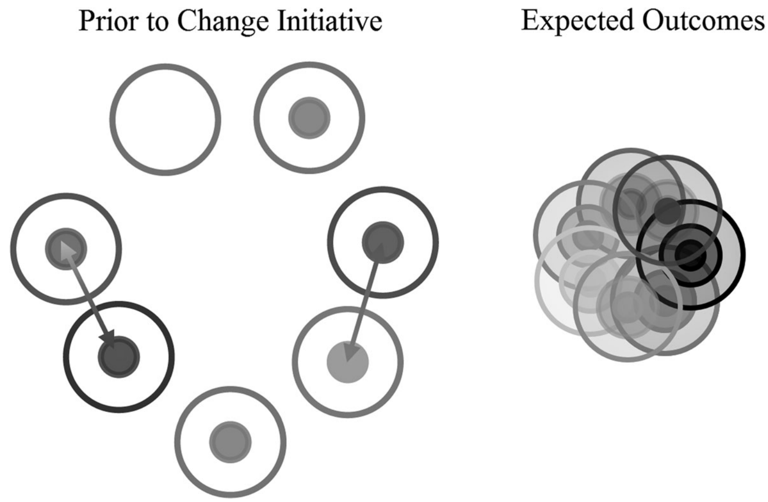

Fig. 1 Isolated units prior to change and the expected outcomes of overlapping communities of practice. Legend: units involved in the change initiative (as unfilled circles) with a core of education innovators (solid circles)

The change leaders' goal of emergent change required relational expertise to identify current communities of practice within the institution and to catalyze future development of communities by attending to collaborators' interests. The theory of change was based upon the assumption that education innovators in the units represented distributed expertise in the system. This distributed expertise could be leveraged by enabling communities to allow for cross-pollination of ideas and to support emerging activities. This cross-pollination of ideas was the generalized conceptual approach of the change initiative; however, the change leaders sought to develop relational expertise to design specific, tangible activities to operationalize this approach and make it actionable. These design decisions were based on preliminary data analysis through formal means as well as a reflective, emergent approach to collaboration with instructional faculty on the change initiative. In this way, the change initiative was developed in the tradition of design-based research: emergent, reflective, and iterative (Cobb, Confrey, DiSessa, Lehrer, & Schauble, 2003).

The change leaders with the help of research assistants (graduate students and postdoctoral scholars) sought to understand how specific units were implementing EBIPs in introductory STEM courses and context-specific challenges faced by faculty in these units. In this study, we particularly focused on the use of social network analysis (SNA) of the disciplinary units as a tool to develop a piece of this relational expertise and show how it led to tangible change activities. The change leaders used this piece of relational expertise, as well as knowledge built through interviews and informal conversations, to guide the strategies and tactics for cultivating communities of practice in the project.

Theoretical frameworks

Relational expertise is an understanding of the perspectives of others within their context that enables collaborative work across values-based boundaries (Edwards, 2012). Edwards conceived relational expertise as a tool within the tradition of cultural-historical theory; accordingly, it is a means for recognizing and allowing for the impact of the history and localized culture of individuals on efforts of collaboration (Edwards, 2010). A relational expert is not only aware of the needs of other collaborators but is also knowledgeable about why these needs are present and how they impact the community. This knowledge allows the expert to negotiate boundaries of interest between collaborators to develop group efforts that attend to the needs of all participants. Relational expertise is critical for emergent change, since emergent change also seeks to develop outcomes that fit the needs of change leaders and participants. Relational expertise is not necessarily correlated with formal position or hierarchy.

In this study, the goal of building relational expertise was to inform collaborations developed as communities of practice that lead to systemic STEM education change across disciplinary units within a single institution. The collaborators are the change leaders, the instructional faculty, and other key players (e.g., administrators). The instructional faculty have a historical and cultural context within their units and within their disciplines that impacts their interaction with the change initiative. The context of participants that influences their perspectives on change in teaching practices includes their understanding of *what* should change, *how* it should change, and *why* it should change, as well as *who* should be involved in making these changes. Based on SNA, we identified social connections as means for developing relational expertise about the participants' context that informs *what* teaching practices should change and *who* should be involved in change. The remaining questions of *why* and *how* this change should occur were answered by the relational expertise that the change leaders developed through other resources and are beyond the scope of this article.

Social connections are useful for understanding the *who* and *what* of the context of collaborators because social connections influence individual behavior (e.g., Pittinsky & Carolan, 2008). Social connections lead to collective sense-making when a group of instructional faculty determines how common underlying values and understandings of learning should be implemented in their shared context (Coburn, 2001). The structure of social connections within units may subdivide the unit into smaller subgroups of individuals who develop similar views of teaching and learning (Quardokus & Henderson, 2015). These subgroups may have divergent values or understandings from one another that lead to misalignment of interests and inhibit coordinated instructional change within the unit. Conversely, the unit may be more unified and have a common shared understanding of education issues. The individuals involved in these connections or subgroups are the *who* that should be involved in change efforts and the topics they are discussing are the *what* of relational expertise related to change.

By identifying the *who* and *what* of relational expertise through social connections, attention is given to individuals choosing to communicate with colleagues about specific topics around teaching and learning. However, it does not necessarily indicate that these faculty members are change agents or that they are choosing to discuss these topics because they think they are most critical for student learning. Rather, the value of identifying these individuals (*who*) and topics (*what*) is that it provides the groundwork for building the *why* and *how* of relational expertise. As the foundation of this relational expertise, it identifies who may be likely to engage in activities and what discussion topics may need to be enhanced to catalyze communities for affecting systemic change. Social connections are the basis of the theory of change of the change initiative: cross-pollination of distributed expertise across the institution through communities of practice.

Methods

Social network analysis (SNA) is a means for detecting social connections and has been used to understand relationships based on teaching activities (Quardokus & Henderson, 2015; Wasserman & Faust, 1994). In SNA, networks consist of individuals and the relationships between them (Prell, 2012). The SNA data were collected via a larger survey administered at the start of the change initiative that was approved by the appropriate institutional review board. Fifty-four percent of faculty members (142 out of 264) in the seven participating units responded to the survey. We discuss the response rates within each unit and the implications for analyses in the "Results" section. The social network survey items analyzed for this study are shown in Table 1.

Respondents identified individuals with whom they discussed teaching and learning as well as the topics that they discussed. Respondents identified topics of discussion from ten provided options (e.g., teaching methods, teaching materials, and student motivation). These topics were chosen by the change leaders. The close-ended survey design was chosen to reduce participant survey burden and to allow analysis within a time frame where they could be used to guide the design of change activities. The specific topics were chosen based on the collective experience of the change leaders who believed they represented tangible teaching topics that could potentially be used as an entry point for discussing improvement of teaching. In contrast, the change leaders chose not to collect friendship networks which would have been more challenging to connect directly to the design of change activities. Finally, demographic data (Table 2) including years of experience teaching, years of association with the institution, and professional title were collected. Professional title was the only piece of data collected from public records (e.g., websites) rather than survey.

Eleven networks for each unit (77 in total) were created based on the responses. One network was the all-encompassing network of connections independent of discussion topic (hereafter, called the all-encompassing network), and ten of the networks were based on each specific topic of teaching and learning. Discussion ties were assumed to be non-directional ties; that is, if one person reported a discussion, then the return relationship

Table 1 Social network survey items

1. Please list one person with whom you communicate about teaching and learning. State your colleague's first and last name. If this colleague does not work at [this institution], please state his or her affiliation. You will be asked follow-up questions regarding this person, and will have the opportunity to list up to ten individuals.
2. What issues of teaching and learning do you discuss with this person? (Check all that apply) • Teaching methods—How to teach • Teaching materials and technologies—How to teach with what • Curriculum—What to teach • Curriculum timing—When to teach what • Assessment—How to measure impact of teaching • Grading issues • Student motivation issues • Student diversity issues • Policy or accreditation issues • Teaching issues related to promotion and tenure

Table 2 Type of demographic data collected for the seven STEM units

Type	Categories
Years of teaching experience	< 1, 1–5, 6–10, 11–15, 16+
Years of association with the institution	< 1, 1–5, 6–10, 11–15, 16+
Professional title	Postdoc, Instructor, Senior Instructor, Assistant Professor, Associate Professor, Professor

was assumed. All calculations and visualizations were made with SNA software (ORA™ from Carnegie Mellon University's CASOS).

To answer the first research question, the seven all-encompassing discussion networks were compared with each individual topic network using Euclidian distance. Respondents could report any person with whom they had discussions about teaching. For the Euclidean distance, ties with individuals outside of the unit were included in the network analysis to identify all topics of interest. For example, if a person in unit A (identified by the name A_01) reported a discussion with a person in unit C (identified by C_01) and an external colleague (identified by Outside_01), then these two individuals (C_01 and Outside_01) were connected to A_01 in the unit A network. In addition, the reciprocated ties (from C_01 to A_01 and Outside_01 to A_01) were assumed. However, person A_01 was not included in unit C networks, unless specifically named by a person in that network.

Euclidean distance is a measure of similarity of networks. It is calculated between two networks by determining how many ties are present in one network but not in the other, that is, the square root of the sum of the squared differences of tie strength for each individual (for calculation, see Wasserman & Faust, 1994). This distance is equivalent to calculating length on a Cartesian plane by finding the square root of the sum of the squared differences of the x and y coordinates, which is commonly called the distance formula. When comparing each specific topic network with the all-encompassing network, the most frequently discussed topic had the most similarity to the all-encompassing discussion network and thus, had the smallest Euclidean distance. The teaching and learning topics whose networks have the smallest Euclidean distance, those that are happening the most frequently within social connections, provide useful knowledge for change leaders interactions with the unit. This analysis allowed the change leaders to develop relational expertise by identifying the aspects of teaching and learning that faculty are discussing currently within the unit. These topics can then be used for cross-pollination with other units or for motivating individuals from these units to participate in the change initiative's activities.

To address the second research question, the all-encompassing discussion network for each unit was investigated to understand *who* was participating in conversations and in what manner. For the subgroup analysis, individuals named by respondents, who were not also members of one of the seven STEM units, were removed from the network to focus on social connections within the units. For instance, in the previous example, the person identified as Outside_01 would no longer be present in unit A's network while the discussion ties between person A_01 and C_01 would remain the same.

Social networks often have subgroups, or pockets of individuals who talk frequently with each other and infrequently with others in the network. These subgroups are likely to share similar views on the topics they are discussing (Quardokus & Henderson, 2015). Subgroups were identified using the Newman and Girvan subgrouping algorithm for each unit (Newman & Girvan, 2004). This subgrouping method looks for subgroups by hypothetically removing the bridges that connect across small groups of tightly connected individuals. If removing bridges creates disconnected networks, then the network is dominated by subgroups. If removing bridges still results in a connected network (that is, there are many bridges between small groups), then subgroups are not a dominating feature. To further understand what may be impacting subgroup formation, the demographic data (title, years of association with the institution, and years of teaching experience) were compared with the identified subgroups to look for patterns of connections. In other words, the subgroup membership was investigated to see if each subgroup was dominated by one demographic category. The subgroups and their demographics inform the relational expertise of the change leaders to identify who may be interested in implementing EBIPs as well as potential subdivisions within the unit that may hinder the propagation of activities.

Results

The results of the study were based on the networks of the seven disciplinary units involved in the change initiative. Table 3 provides descriptive analysis of the all-encompassing discussion networks for the seven units (labeled A through G). These network-level metrics are for the networks used for subgroup analyses.

The first three metrics of Table 3 (the number surveyed in the unit, the response rate within the unit, and the number of members of other units) provided information about who was in the network. The metrics

Table 3 Descriptive network values for each unit's all-encompassing discussion network

	A	B	C	D	E	F	G
Individuals in the network							
Number surveyed in unit	21	34	36	57	40	26	47
Response rate within unit	71%	50%	39%	56%	43%	77%	57%
Number of members of other units included in the network	1	1	1	2	1	2	3
Organization of ties in the network							
Number of components	1	2	3	7	4	1	6
Individuals in main component	16	20	11	22	14	22	19
Density	0.10	0.05	0.03	0.02	0.02	0.07	0.02
Centralization (total degree)	31%	23%	17%	7%	13%	28%	8%
Subgroup modularity	0.35	0.46	0.30	0.67	0.61	0.47	0.72
Subgroup number	5	6	5	10	7	6	10

"number of members of other units" identified how many individuals were named by respondents who were members of one of the other STEM units. These metrics showed that at the start of the project relatively few ties existed *across* unit boundaries. For the change leaders, this was important because it meant cross-pollination communities of practice needed to be developed rather than harnessing pre-existing, inter-unit communities. In addition, the low response rates (< 50%) within the units of C and E are a limitation of this study, and may indicate that the survey data were insufficient to illuminate the context of these units. On the other hand, it may also indicate a lack of interest in education initiatives within these units. The change leaders responded by placing extra emphasis on other methods of building relational expertise to work with these units, including interviews and informal discussions.

The remaining metrics in Table 3 characterized the way the social ties were positioned in the network: the number of components, individuals in the main component, density, centralization (total degree), subgroup modularity, and subgroup number (for calculation, see Newman & Girvan, 2004 and Wasserman & Faust, 1994). These metrics helped the change leaders determine whether a network was likely to have a unified approach to teaching and learning or a diversity of ideas across subgroups. A unified network is likely to have similar views about teaching and learning because social connections allow for the sharing of ideas and the collective sense-making (Coburn, 2001; Quardokus & Henderson, 2015). For example, unit A had a unified network that was likely to have shared ideas related to teaching and learning, whereas unit D was characterized by subdivision and plausibly had multiple perspectives on teaching and learning within the unit. It is likely that unit D's response rate contributed to this variance. However, the change leaders' knowledge of the unit (including one change leader who was a member of the department) confirmed that these differences were indicative of unit D's social relationships and not simply an artifact of the response rate. These units are used as examples of the information that the change leaders reflected upon when designing specific activities for catalyzing communities of practice.

Components of the network are clusters of disconnected subnetworks within the network. The *main component* is the cluster with the most individuals within it. Unit A's single and large main component (containing everyone who responded to the survey) indicated an integrated network for sharing ideas about teaching and learning. Unit D has the most components; it has many smaller sets of individuals who are not connected, a less unified network.

The *density* of the network refers to the number of ties present in the network divided by the number of potential ties that may occur in the network. Unit A had a high density, which indicated many opportunities for the sharing of knowledge, whereas unit D had a low density and less opportunity for knowledge to be shared and created in the network.

The *total degree centralization* is the degree to which the ties in the network are concentrated in a few nodes. In unit A, a high percentage of degree centralization meant that a few key individuals were linked to many others in the network and likely connected with each other to develop a unified understanding of teaching and learning. In unit D, the discussions were less concentrated in a few nodes and more spread throughout the network.

The *subgroup modularity* is the value assigned by the Newman and Girvan algorithm that describes how easily the network was divided into subgroups. This number is bounded by one and zero, where a one means the network is clearly separated into subgroups. Finally, the *number of subgroups* identifies how many subgroups are present in the network. The individuals who do not have any ties are identified as one type of subgroup. Unit A had only five subgroups and a low modularity which indicated a more unified approach to teaching and learning. Again, unit D had many subgroups and a high modularity, indicating a more disconnected network.

These metrics helped identify the range of networks within the units. Unit A is the most unified; it has only one component, high density, high centralization, low modularity, and only five subgroups. On the other hand, unit D had seven components, low density, low centralization, high modularity and many subgroups. Unit D required more analysis to identify how divisions in the network may impact the work of the change initiative.

Identifying topics of interest with Euclidean distance

The Euclidean distance between discussion networks was used to answer the first research question: What topics of teaching and learning are most important to faculty in disciplinary units as demonstrated by their reported frequency of discussion by unit members? Again, Euclidean distance measures how similar two networks are. For example, Fig. 2 shows the all-encompassing network in unit A and the network of communications about tenure and promotion related to teaching in unit A. These two networks have a large Euclidean distance because they only have seven ties in common.

Euclidean distance was calculated between the all-encompassing network of a unit and each topic network for that unit. To report the findings, Euclidean distance was then used to rank each topic from one (most similar to the all-encompassing network, smallest Euclidean distance) to ten (least similar, largest Euclidean distance). Table 4 shows the ranking of each topic by each unit. The topics are listed in order of average rank across all the units. In unit A, for example, *Curriculum* was discussed most frequently and was given a rank of one. This analysis allowed the change leaders to uncover both what topics were commonly discussed within specific units as well as cross-unit trends. The change leaders used the knowledge that a topic was given a high rank as relational expertise by employing that topic as a catalyst for building discussion about EBIPs. In addition, the change leaders considered when discussions needed to be instigated to recognize the importance of some of the lower ranking topics in relation to education improvement.

Discussion in the seven STEM units often included topics of teaching and learning related more directly to daily instructional activities with a course (e.g., methods, assessment, teaching materials, and technologies), or how the courses fit together at the program level (curriculum). In contrast, discussions about systems-level topics (promotion and tenure, student diversity, and policy and accreditation) occurred less frequently. These topics are considered systems-level because they have indirect impact on the day-to-day activities in the classroom. Guidelines for tenure and promotion and policy and accreditation form institutionally based systems that affect instructional decisions of faculty members. These results indicate that faculty may be more likely to take these topics as the immutable context that forms the “system” in which specific daily instructional practices are considered. For example, if promotion and tenure processes place great weight on student evaluations of teaching, faculty may be more likely to give higher grades (Johnson, 2006) and matching student expectations as opposed to experimenting with EBIPs or discussing change in these policies. Similarly, issues of student diversity are considered in the context of a socially based system that impacts classroom practice. As with the policies, faculty may consider systemic practices that influence diversity as an immutable context where they do their work. The change leaders were particularly interested in the implications of this result because of their specific focus on systemic education change within the institution toward more effective and inclusive practice.

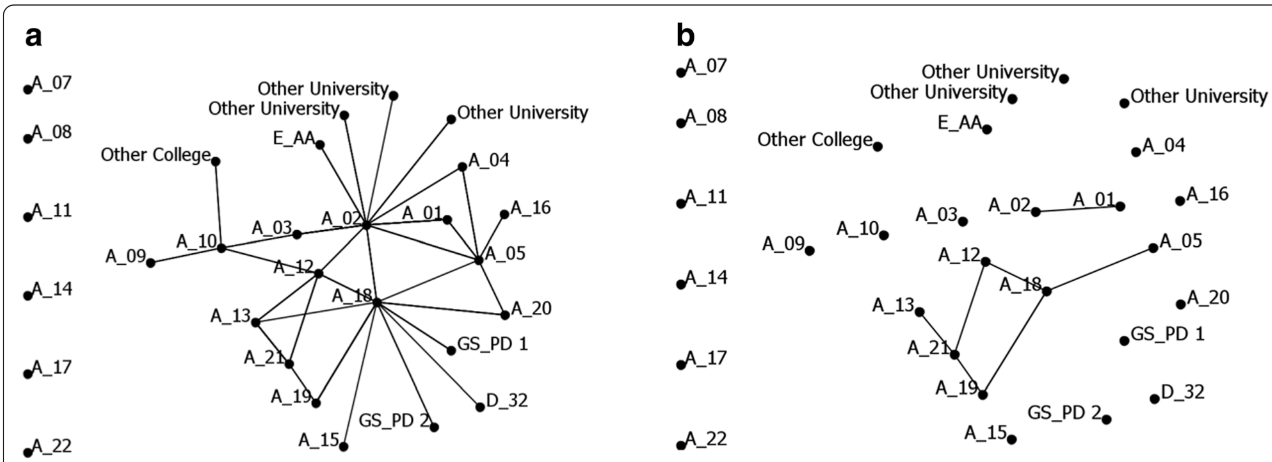

Fig. 2 a All-encompassing network in unit A. **b** Discussion network of teaching issues related to promotion and tenure in unit A

Table 4 Ranking of Euclidean distance of topic networks compared with the all-encompassing networks of each unit

	Average rank	A	B	C	D	E	F	G
Teaching methods	1.9	2	3	1	3	1	1	2
Curriculum	2.9	1	4	3	2	4	5	1
Student motivation	3.0	5	1	4	1	2	3	5
Teaching materials and technologies	4.0	3	2	5	5	3	4	6
Assessment	4.0	6	5	2	4	5	2	4
Grading	6.4	7	7	6	7	7	8	3
Curriculum timing	6.7	4	6	9	6	9	6	7
Promotion and tenure	8.0	9	8	7	8	6	10	8
Student diversity	8.7	8	9	8	9	10	7	10
Policy and accreditation	9.4	10	10	10	10	8	9	9

It is possible that discussion frequency does not represent the interest level of each topic. For example, daily activities may be discussed more often because they represent an immediate necessity. In contrast, faculty may not see systems-level discussions as immediately affecting the classroom. However, systems-level structures do greatly affect day-to-day classroom practices, so change leaders were compelled to consider how individuals within the systems can be encouraged to look past immediate urgency and think about how to positively influence these structures.

This analysis built the relational expertise of the change leaders by identifying common topics of discussion across units (daily instructional activities and curriculum) and less common topics (systems-based), as well as where interests vary between units. This expertise was used in two ways. First, it allowed the change leaders to understand the topics upon which faculty currently focused, and they could then design activities that were commensurate with these faculty interests. Second, change leaders identified critical topics (systems-based) for which they needed to create more opportunities for conversations. The specifics of how the change leaders have used these findings are described in the "Discussion" section.

Identifying patterns of connections with subgroup analysis

Subgroups and demographic data were used to answer the second set of research questions: Who is involved in discussions regarding teaching and learning as measured by the social connections that are identified? And, what subgroups do they form? First, subgroups were identified in the all-encompassing networks using the Newman and Girvan algorithm. Next, the demographic data of years of association with the institution, years of teaching experience, and professional title were overlaid on the subgroups to find subgroups that were dominated by a single demographic category.

If subgroups were dominated by a specific demographic, change leaders can use this information to design change initiative activities. Change leaders would know what demographic of faculty members were having separate discussions about education and that ideas were not extending to the entire unit. This knowledge is salient given the power differential among faculty with different demographics. For example, if all the individuals with 16+ years of teaching experience were speaking with each other and not with the newer faculty members, then it is likely that changes made by newer faculty would never be communicated with the experienced faculty who have higher status. Change leaders could use this information to target integration of newer faculty into discussions about teaching with experienced faculty members.

When compared with subgroup affiliation, professional titles were the only demographic that often corresponded with subgroup affiliation. For units A, B, C, and D, a division was evident between subgroups of fixed-term faculty (instructors and senior instructors) and tenure-track faculty (assistant professor, associate professor, and professor). In these units, at least one subgroup was dominated by fixed-term faculty. Units E, F, and G only have a limited number of fixed-term faculty members and therefore, did not have this trend. However, in unit F, full professors were often in different subgroups than assistant professors, indicating a division based on years of experience as a professor. Units E and G did not have discernable patterns.

Each units' subgrouping results were used to inform the change initiative. This section elaborates the subgroups in unit D because it is an extreme example of the social division. In the other units, the pattern of behavior was less pronounced and likely would have less impact on change efforts. In unit D, a clear division existed between fixed-term and tenure-track faculty members. As Table 2 shows, unit D had a high modularity and many subgroups. Figure 3 shows the subgroups of unit

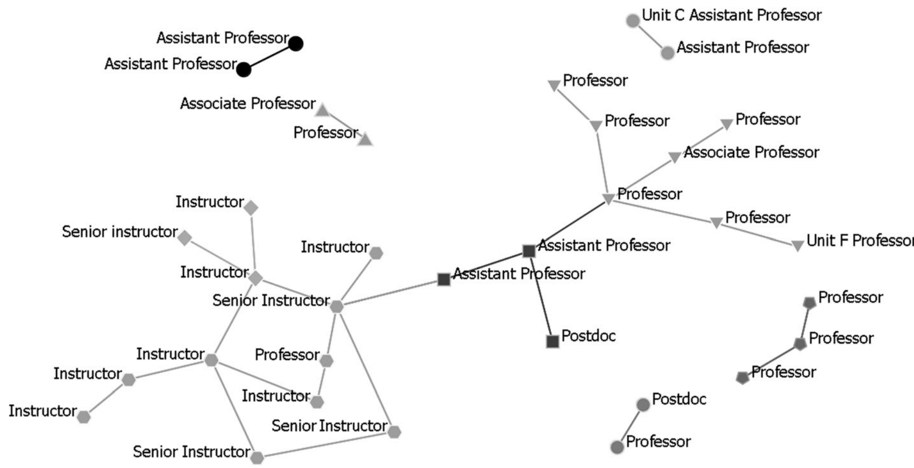

Fig. 3 Subgroups of unit D denoted by shape and color of nodes and ties

D as denoted by the shapes and shades of individuals and by professional title (individual labels). We group the postdocs, instructors, and senior instructors as fixed-term faculty members, and the assistant professors, associate professors, and professors as tenure-track faculty members. The fixed-term faculty members are located on the left side of the main component (except for one professor) and the tenure-track faculty are located on the right of the main component. In addition, assistant professors form a bridge between the two larger clusters.

From the perspective of a unit-wide change initiative, the separation between tenure track and fixed-term subgroups highlights the needs to support communication about teaching improvement throughout unit D. The fixed-term faculty in this unit are primarily responsible for teaching the large, lower-division courses that are the focus of this change initiative while the tenure-track faculty more commonly teach the smaller upper division courses. If both groups are not aligned in the change strategy, students may first face a learner-centered environment using EBIPs and then face a transition to classes taught with more traditional styles. Additionally, in the face of challenges like student resistance, the authority of the higher status tenure track subgroup may impede the ability of fixed-term faculty to enact instructional changes. While this trend of separation between the two subgroups of faculty members was illustrated for unit D, similar patterns occurred in almost every unit. For example, in unit F there was a subgroup of mostly assistant professors and a subgroup of mostly full professors and they were bridged by associate professors. Understanding and incorporating this relational expertise was useful for the change leaders to consider when developing systems level strategies around student learning, as discussed next.

Discussion

One of the goals of this study was to use SNA to guide the design of communities of practice for a collaborative emergent change initiative involving seven STEM units. The study was guided by research questions that asked about aspects of the context of disciplinary units to build relational expertise: *what* aspects of teaching and learning are important to participants and *who* is involved in discussions about teaching and learning and what subgroups do they form. The change leaders recognized two main points from the answers to the research questions:

1. Faculty members are discussing topics more related to daily instructional practices or how these practices fit into a program, while fewer discussions include systems-level topics.
2. Social segregation within teaching discussions is associated with status, e.g., fixed-term faculty members are separated socially from tenure-track faculty and assistant professors are separated from professors.

In addition to the relational expertise built through SNA, the change leaders also used their personal knowledge (many of them are embedded in the units), informal discussions, and information from interviews to inform project design. From this knowledge, the change leaders designed several specific activities to enact their theory of change, including a Learning Assistant program, regular meeting with key individuals within units, a revised teaching evaluation process, and a focus on sustainability of the project after the funded period had concluded. While these all were informed to some degree by the relational expertise of the change leaders, we next focus on two illustrative change activities that emerged:

1. A STEM faculty community that met once a term to discuss relevant topics related to teaching and learning.
2. An action research fellowship that fixed-term and tenure track faculty could join to support their personal implementation of EBIPs and that change leaders could use to provide institutional recognition for instructors' work.

While the theory of change was identified before the initiative, neither of these communities were planned a priori, but rather emerged from the growing knowledge and understanding in real time. In this section, we show how these two specific activities were responses to the relational expertise developed through social network analysis. We recognize that other design solutions are possible but focus on the specific activities that were implemented in this change initiative.

First, the change leaders wanted to develop cross-unit relationships around EBIP development and implementation. From the network analysis, it was clear that cross-unit ties occurred infrequently and that members within units stratified by status positions. It was also clear that conversations focused on the specific context of classes or sets of classes toward a program, and that other important "system" level aspects were not frequently discussed. The resulting activity became known as "Faculty, Food, & Fun" and was used by the change leaders to facilitate targeted discussion of relevant teaching and learning topics with faculty from various units. This casual event encouraged both structured and unstructured conversations about teaching and learning within a 2-h meeting deliberately grouping participants from different units and at different ranks. The motivation for the activity was to develop a community of individuals across units and ranks who could share expertise and provide an opportunity for discussing systems-level topics. The Faculty, Food, and Fun event met three times during a year (Fall, Winter, and Spring term). Each event allowed time for making connections with other faculty members and change leaders. The event has occurred ten times and attendance has ranged between approximately 25–50 faculty members. Often a critical opinion leader was invited to ground discussion on a specific topic. At these meetings, the change leaders built on the topics that were high ranking within the units as well as provided a context for considering systems-level impacts and changes.

Second, the change leaders developed a more structured community of Action Research Fellows (ARFs). The ARF program used a cohort-based model to support the work of implementers of EBIPs through scholarship into their classroom practices and through broader recognition at the institution. Instructional faculty applied for the program by proposing a research project on EBIP implementation in their classroom. This community was open to any faculty member, but mostly fixed-term instructors participated. Across two cohorts, 18 fixed-term, five tenure-track, and one advisor representing all seven units have participated. The expectation was that fixed-term faculty members were the most likely to participate. Thus, the ARF program could be used to promote and recognize the work of instructors in implementing EBIPs. They were awarded a small stipend for participation and received an official letter of participation for inclusion in professional portfolios that was also sent to their unit head and dean. After a Fellow was selected, he or she was invited to participate in ARF community events as well as many smaller interactions with an education research postdoc or graduate student to design, implement, and analyze their study. The fellowship lasted for 1 year. In the early fall, Fellows learned about action research, study design, and the institutional review board. In winter, Fellows collected data and began analysis, and in spring, they shared their work at a poster session held at the institution. Fellows were also expected to share findings internally with their unit and at a relevant conference. This communication of findings and the recognition of the work of fixed-term faculty members helped to break down the division between fixed-term and tenure track faculty that was identified within the social networks.

Relational expertise helped the change initiative design programs that could develop collaborative relationships to address challenges and strengths of the context. The change leaders wanted to create a change initiative that aligned with the needs of diverse educators across the seven STEM units. The SNA analysis highlighted the need to develop cross-unit ties on relevant topics to promote EBIPs and to extend discussion from the specific context of faculty work to the system within which they were players. Two examples are provided of how this need was met. A casual community meeting of faculty allowed both formal and informal discussions about teaching and learning and led to systems level discussions. In addition, a more structured community was developed to support the implementation of EBIPs by instructional faculty and to acknowledge their work across the institution. The SNA provided evidence that was instrumental in conceiving and constructing these communities.

Implications

Instructional improvement initiatives in post-secondary STEM programs are needed to advance students' preparation for professional work in STEM disciplines and to develop them as informed, decision-making citizens. These change initiatives often work across disciplinary boundaries, making associated work complex (Bouwma-Gearhart, 2012; Bouwma-Gearhart et al., 2014). Initiatives must both aim to fit the needs of a diverse range of participants, as well as work to benefit from contrasting disciplinary knowledge, pedagogical practices, and perspectives. In this study, we show how SNA was a useful tool to develop the relational expertise of change leaders. SNA was used to identify the prevalent topics of teaching and learning in faculty members' discussions and to understand how social structures may support or inhibit change.

The findings, while not generalizable, provide insight into the context of an educational change initiative at a large, research university. First, with respect to topics of teaching and learning, discussions tended to focus on the specific delivery in the classroom and of the program. Discussion on issues of the broader education "system" was uncommon, which limited the attention to important issues such as diversity and inclusion or systemic biases in the reward structure that discourage innovative instruction. This focus on individual courses results naturally from organizational structures where the course is the primary "unit" of evaluation for both faculty and students. We need to shift faculty dialog beyond their individual classes in order to address these very structures that limit improvement to instructional practice. The collective activity that is needed to break down restrictive structures begins with more prevalent conversations about those structures. It is important to provide time and space for faculty members and administrators to engage in these broader discussions such as in our "Faculty, Food, & Fun" community. However, we also recognize that dialog on structures only goes so far, and the role of change leaders only starts with determining the impact of these systems; they also need to productively restructure them.

Second, in many of the STEM units, individuals aggregated in subgroups with others of the same professional track affiliation or rank. Aggregation by years of experience has been shown to negatively impact instructional change outcomes in elementary schools (Spillane, Healey, & Kim, 2010) and likely has negative influence on instruction in post-secondary education. However, it is a localized context that differs between STEM units (e.g., Quardokus & Henderson, 2015). A challenge at universities like the one studied here is in promoting productive conversation among faculty that are grounded in evidentiary bases for improved instructional practice. Homogeneous subgroups of faculty within a unit can reinforce less productive anecdotal approaches to instruction. When discussion is isolated to a single unit, status positioning also plays a role enabling faculty to make claims based on position and power. Identifying instructional subgroups and promoting social "mixing" can lead to a better shared understanding towards instruction that is grounded in evidence. By encouraging mixing across units, the detrimental influence of status on choices of instructional practice and educational policy decisions can be mitigated.

Conclusions

We assert that it is important for change leaders to understand the topics of discussion around teaching and learning (the what) and the social structures of the units they seek to influence (the who) as well as the how and the why. By completing analyses like the SNA reported here early in a change initiative, relational expertise can be developed and used to design activities and communities that equitably engage the wide range of participants toward meaningful, emergent change. Change initiative activities need not be entirely prescribed and premeditated, but rather they can emerge as part of the process by using relational expertise to learn about the perspectives and values of the actors within the community. Participation can shift with time as change leaders identify distributed pedagogical expertise within the community and enable those faculty greater authorship of their expertise. In this way, leaders encourage faculty to become more central participants in the change initiative. Further research is needed to understand processes by which distributed experts are incorporated into the change initiative to take up more and more central roles to become agents of change themselves.

Abbreviations

ARF: Action Research Fellow; EBIP: Evidence-based instructional practice; SNA: Social network analysis; STEM: Science, Technology, Engineering, and Mathematics

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Availability of data and materials

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Authors' contributions

KQF analyzed and interpreted data and led the drafting and revising of the manuscript. AS contributed to data collection, interpreted data, and participated in drafting and revising the theoretical frameworks and results. JBG guided development of data collection instruments, guided data collection, provided feedback on results, and revised drafts of the paper. MK interpreted data and results, and drafted and revised the paper. All authors have read and approved the final manuscript.

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