Connections Among University Faculty Engaged in the First Two Years of Engineering and Their Impact on Faculty Attitudes and Practice

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Connections Among University Faculty Engaged in the First Two Years of Engineering, and Their Impact on Faculty Attitudes and Practice

Abstract

This research paper examined the connectedness of STEM faculty to others both within and across academic departments who might be potential resources for diffusion of Learner-centered practices, and the impact of participants' social networks on their Learner-centered beliefs and practices. The research question under investigation was: To what extent is the degree of social connectedness among faculty within and among STEM departments related to the degree of implementation of Learner-centered practices? Participants were recruited from Physics, Chemistry, Mathematics departments, and from departments in the College of Engineering. The sample began with 21 randomly-selected faculty from each department engaged in the STEM instruction of first and second year engineering students. The second level consisted of the colleagues identified by the first level as people they utilize as resources for improving their instruction. The connectedness of faculty in the network was examined using network analysis, focusing on both number of connections, and depth of connections. Attitude and Observation Protocol measures were used as outcomes. Results show that faculty classified as Learner-Centered had deeper and more extensive social networks. Results are discussed in terms of the need for intra- and inter-departmental faculty professional development experiences that both introduce and encourage faculty to trial new tools and techniques, but that also run for the long-term, supporting collaborative organizations of faculty working together to transform early engineering experiences.

Introduction

Recent research has shown that learner centered practices are infrequently used in engineering pedagogy. Learner Centered instruction is defined by the American Psychological Association as comprising a set of cogntive and metacognitive factors, motivational and affective factors, developmental and social factors, and individual differences (see Table 1)[1]. It is assumed, generally, that to be learner centered, pedagogies need to simultaneously address key concepts, skills, and dispositions in a domain, *and* account for the knowledge, predelictions, and social characteristics afforded by students in a manner that is dynamic, adaptive, and personally relevant.

In a recent meta-analysis of 119 studies across grades K-20, Cornelius-White, found that learner-centered variables such as non-directive verbal interactions, incorporation of higher-order thinking, encouraging learning and challenge, and adapting to individual and social differences correlate significantly with cognitive and affective student outcomes (e.g., mathematics achievement, science achievement, participation, motivation, and others). Relationships among these variables average r=.34, indicating that the overall influence of learner centered practices accounts for about ten percent of desired outcomes--a significant relationship.[2]

The hypothesis underlying the study reported here is that faculty practices are the primary mechanism by which potential changes in student learning and motivation are effected. While faculty attitudes may support practical change, and while student beliefs and attitudes may mediate their learning behavior, it is precisely the conditions of learning that are responsible for the nature and extent of learning, *and* students beliefs about, and self-regulatory strategies recruited while learning. One of the problems in studying learner centered practices is that they cast a fairly wide net. Many different pedagogical techniques may be employed effectively and be called “learner-centered.” As such, learner-centered instruction can be thought of as heuristic—incorporating rules of thumb that can be used in the moment to tailor instruction to the needs of students. The following heuristics have been shown to be effective in structuring learner centered pedagogical environments.[3] As can be seen, learner-centeredness requires a shift from presenting content to enervating and supporting the actual learning modalities and outcomes for students.

Table 1. American Psychological Associated Learner Centered Psychological Principles

Cognitive and Metacognitive Factors
Nature of the learning process: The learning of complex subject matter is most effective when it is an intentional process of constructing meaning from information and experience. **Goals of the learning process:** The successful learner, over time and with support and instructional guidance, can create meaningful, coherent representations of knowledge. **Construction of knowledge:** The successful learner can link new information with existing knowledge in meaningful ways. **Strategic thinking:** The successful learner can create and use a repertoire of thinking and reasoning strategies to achieve complex learning goals. **Thinking about thinking:** Higher order strategies for selecting and monitoring mental operations facilitate creative and critical thinking. **Context of learning:** Learning is influenced by environmental factors, including culture, technology, and instructional practices.
Motivational and Affective Factors
Motivational and emotional influences on learning: What and how much is learned is influenced by the learner’s motivation. Motivation to learn, in turn, is influenced by the individual's emotional states, beliefs, interests, and goals, and habits of thinking. **Intrinsic motivation to learn:** The learner’s creativity, higher order thinking, and natural curiosity all contribute to motivation to learn. Intrinsic motivation is stimulated by tasks of optimal novelty and difficulty, relevant to personal interests and providing for personal choice and control. **Effects of motivation on effort:** Acquisition of complex knowledge and skills requires extended learner effort and guided practice. Without learners’ motivation to learn, the willingness to exert this effort is unlikely without coercion.
Developmental and Social Factors
Developmental influence on learning: As individuals develop, they encounter different opportunities and experience different constraints for learning. Learning is most effective when differential development within and across physical, intellectual, emotional, and social domains is taken into account. **Social influences on learning:** Learning is influenced by social interactions, interpersonal relations, and communication with others.
Individual Differences Factors
Individual differences in learning: Learners have different strategies, approaches, and capabilities for learning that are a function of prior experience and heredity. **Learning and diversity:** Learning is most effective when differences in learners’ linguistic, cultural, and social backgrounds are taken into account. **Standards and assessment:** Setting appropriately high and challenging standards and assessing the learner and learning progress - including diagnostic, process, and outcome assessment - are integral parts of the learning process.

1. The actions of the instructor focus on students learning as opposed to presenting material.

2. In ethically responsible ways, instructors share decision making about learning with students. Teachers control less, but students are involved more.

3. Content is used to build a knowledge base, to develop learning skills and to foster learner self-awareness of their abilities. Teaching approaches account for students' learning modes and strategies.

4. Instructors and students, together, create learning environments that motivate students to accept responsibility for learning.

5. Assessment activities are used to promote learning and to develop self and peer assessment skills, not to evaluate performance primarily.

Unfortunately, research shows that learner-centered practices are used only infrequently by post-secondary STEM faculty.[7] Part of the problem concerns the fact that an instructor's perception of student-centered pedagogy may not align with the reality of their classroom practice. Ebert-May et al., for example, reported on results of a national biology professional development program consisting of 6-12 days of workshops on scientific teaching over three years.[4] While faculty engaged in the professional development self-reported they were using a student-centered learning strategy, observation of their practice revealed that, in reality, three-fourths were lecturing with instructor-centered teaching. The authors maintain that the professional development was not sufficient to sufficiently change the nature of their teaching practice. So the majority of participants, had not actually progressed into a true embodiment of learner centered practice. Ebert-May et al., hypothesized that a possible reason for the lack of efficacy of the intervention was lack of social support for their changing beliefs, thus hindering their translation into new classroom routines and activities.

In support of this general hypothesis, McKenna et al., studied engineering faculty developing student-centered conceptual change instructional methods. Faculty worked collaboratively with learning scientists to promote effective task and instructional sequence design. The researchers found that the greater the extent of collaborative reflection between engineering faculty and learning scientists, the greater the shift toward student-centered practices.[5]

Other researchers (e.g., Borrego et al.) have used Everett Rogers' model of diffusion of innovations to characterize faculty change through professional development.[6,7] They found that faculty tend to only progress through the earliest stages of change: *awareness* and *interest,* and tend not to move to actual practice. The key issue here is that, without change in students' learning experiences, little chance of improving learning and motivational outcomes exists. Alternatively, if change occurs too slowly, it may be so ineffective, it may take years or decades for instructional practices to catch up with students needs. Altogether, this paints a pretty bleak picture of faculty practice and faculty development. However, Borrego et al., also cite confincing evidence that providing support *in the form of collaborative interactions among faculty* during the third and fourth *decision* and *trial* stages of can provide a successful progression to the higher stages of diffusion of innovation.

Social Network Analysis

Recently Judson & Lawson studied the degree of faculty connectedness in high school STEM teachers.[8] They recorded the degree to which teachers served as resources for others, in a addition to seeking out others for assistance in improving their instruction. They found that the degree to which individuals served as sources of information—i.e., where others came to them for help, strongly predicted their implementation of constructivist pedagogies. In the current study, these prectices, assessed on the Reformed Teaching Observation Protocol[9] are deemed close analogs to Learner-centered practices as defined by the APA and Weimar.

These findings suggest that social support for faculty is a key mediating variable determining faculty practice. There have been many articles reporting how faculty, particularly adjuncts and teaching faculty feel unsupported and isolated in University STEM departments.[10] Where practical change occurs, research has shown that collaborative professional development can be one of the key design elements of the effort.[4]

This study examines the extent of faculty social networks across University STEM departments, and the relationship between faculty connectedness with their learner centered attitudes and classroom practices.

Research Question

The research question under investigation was: To what extent is the degree of social connectedness among faculty within and among STEM departments related to faculty attitudes about, and their degree of implementation of, Learner-centered practices?

Method

Participants

Participants were recruited from Physics, Chemistry, Mathematics, and Teacher Education departments, and from seven departments in the College of Engineering (Mechanical/Aerospace, Civil, Materials, Biological, Electrical, Computer, and Freshman Engineering) at a large, urban, Southwestern University in the United States. Sampling proceeded in two phases: 1) The sample began with 21 randomly-selected faculty from each department engaged in the STEM instruction of first and second year engineering students (13 Engineering, 4 Physics, 2 Mathematics, and 2 Chemistry); 2) The second level consisted of 80 additional colleagues identified in an interview process by the first level participants as people they utilize as resources for improving their instruction. Faculty were provided small stipends as compensation for their time.

The 21 originally sampled were interviewed, observed, and surveyed in-depth regarding their attitudes and teaching practices. The remaining 69 were surveyed in the social network analysis portion of the study only.

Interviews

This study utilized four data collection methods: Faculty interviews, faculty surveys, observation protocol scores and qualitative classroom observation.

Each faculty member in the study participated in one one-hour semi-structured interview focused on their practice, and on the supports and barriers they encountered in their efforts to improve their practice. Interviews consisted of twenty-four questions focusing on topics of teaching practices, teaching resources used, teaching environment, course and departmental policies, self and departmental evaluations, and departmental and interdepartmental collaboration. Interviews were audio-recorded upon permission.

The Glaser and Laudel approach to qualitative content analysis was chosen to analyze the interview data. Qualitative content analysis is a theory-guided method that extracts *qualitative* content using units of meaning originating from the same theoretical framework that guided the *quantitative* data collection. The goal of this analysis was to determine contextual and potentially causal factors in the qualitative data that "mirrors" the quantitative.[11] Specifically, we used this method to ascertain the common resources faculty used to support instruction, and then determine the extent to which use of resources supported Learner-centered instruction as defined by the quantitative measures (below).

To obtain a larger sample for the social network analysis, a key portion of the interviews involved a set of questions focusing on the social network related to instruction within which each participant operated. Three questions were asked:

1. With whom do you collaborate regarding improvement of instruction?
2. With whom do you discuss teaching-related topics? and
3. Who comes to you to discuss instruction?

The interviewer probed instructors to create a comprehensive list of others, both within their department and outside their department. Responses also indicated that several faculty rely on colleagues outside their university for information and support. A total of eighty-three persons were nominated using this process, across all participants. Outside nominations were discarded; one interviewee's quantitative data was incomplete and discarded, leaving 80 faculty in the remaining pool.

Approaches to Teaching Inventory (ATI)

In addition to the interview, each of the 21 original instructors completed a twenty-two item revised edition of the Approaches to Teaching Inventory survey to measure faculty perceptions about their own teaching. The ATI is a valid and reliable self-reporting tool designed by Trigwell and Prosser assesses the extent to which faculty teach with an approach toward instructor-centered knowledge transmission versus student-centered conceptual change.[12] Items on the ATI fall into four dimensions: 1) Conceptual Change Intention, measuring the degree to which instructors are aware of, and support the development of student understanding in the class (e.g., I see teaching as helping students develop new ways of thinking in this subject); 2) Student-Centered Strategies, measuring the extent to which instructors utilize pedagogical strategies that focus on student learning (Teaching in this subject should help students question their own understanding of the subject matter); 3) Information Transmission, the extent to which the instructor emphasizes getting information to the student (e.g., I think an important reason for running teaching sessions in this subject is to give students a good set of notes); and 4) Teacher-Focused Strategies (e.g., My teaching in this subject focuses on delivering what I know to the students). The first two dimensions promote Student-Centered classroom practice, while the latter two promote Teacher-centered classroom practice. Reliabilities of the subscales range from alpha = .73 to .75. Of course, it was expected that all instructors will incorporate some beliefs from each of these 4 dimensions to more or less degree in their own teaching perspective.

Classroom Observation Protocol and Qualitative Observations

For each course, at least three classroom observations were conducted. Six faculty had 4 observations, and two faculty were observed 6 times, for a total of 96 observations. Sections to be observed were randomly selected from the list of required freshman engineering courses taught in each department. The Reformed Teaching Observation Protocol (RTOP) was used after each observation to identify specific teaching practices associated with reformed teaching. The RTOP is a classroom observational protocol that quantitatively characterizes the extent to which faculty implement student-centered behaviors in their own classroom practice. It has high reliability and validity. Published reliabilities of RTOP subscales are: Lesson Design and Implementation (alpha = .915), Propositional Knowledge (alpha = .670), Procedural Knowledge (alpha = .946), Communicative Interactions (alpha = .907), and Student/Teacher Relationships (alpha = .872).

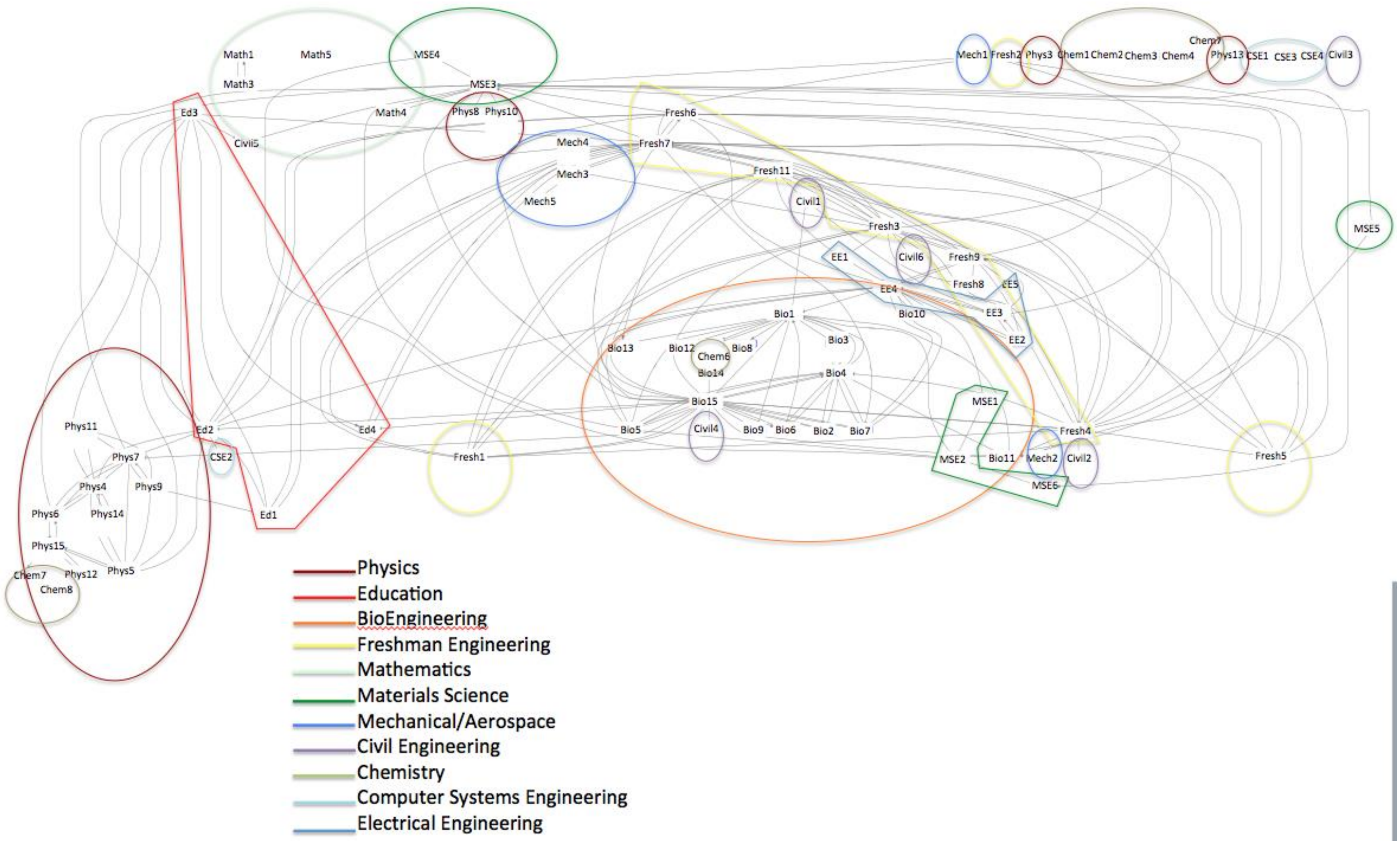
The overall RTOP has a reliability of alpha =.954. As classroom practice can vary across days and specific learning objectives, RTOP scores for each participant's three observations were averaged to gain a typical view of their practice, resulting in a single set of scale scores for each participant. In addition to RTOP scores, qualitative classroom observation field notes were gathered during each course observation including details about class environment and student-instructor interactions. The classroom observation field notes were used to provide relevant information in conjunction with the reformed protocol results and to provide any needed context when examining the relationship between the classroom teaching practices as reflected in the RTOP score and the teaching beliefs reflected in the instructor interviews and survey responses [9].

Social Network Analysis

Social Network Analysis is a set of analysis techniques that characterize the number and type of connections among members of a social system. It uses mathematical concepts from graph theory to map the links (relationships) between nodes (people). Any adjacency matrix listing the connections among individuals can be turned into a vertex-edge graph, which illustrates visually, the density of connections within and cross-connections across departments. We follow the method of Judson & Lawson[8] who used this method fruitfully to predict the relationship between high school STEM teacher connectedness and dimensions of the RTOP. Specifically, we study *in-degree*, the extent to which colleagues approach a participant to discuss teaching practices, and *out-degree*, the extent to which participants *seek out* another to assist in their own teaching practice.

Faculty names were put into columns in an online survey matrix. Each participant was asked to check a box indicating whether they "go to" another colleague to share teaching strategies, and then asked to check a box whether each faculty member "comes to" them to share teaching strategies. Faculty responses were then arranged into an adjacency matrix showing in-degree and out-degree. These responses are then displayed using a directed graph (digraph) to show the

Figure 1. Directed Graph of Faculty Connections, Color-Coded by Departmental Affiliation



directionality of influence for each faculty member. The digraph is drawn, placing faculty with the most common connections in proximity, and color-coding their departmental affiliation.

Results

Social Network Analysis

The proximity matrix for all 80 participants was analyzed using Matlab 1015b biograph function. Figure 1 shows the connectedness among all participants. Both the density of connections within departments, and the connectedness across departments are of importance here. It is clear from the area comprised by each department that there is much more collaboration in-department than across-departments. It is also clear from the density of connections in each department that the interconnections among members of BioEngineering, Physics and Freshman Engineering is higher than the other departments. These departments contain many participants involved in the design and implementation of first year instruction for engineers, they have cultures of collaboration and, importantly, they have histories of projects and funding that support faculty collaboration for the purpose of improving instruction. It is also apparent is that there are few connections across departments, with notable exceptions from the Freshman Engineering Department, whose faculty hold positions concurrently with disciplinary departments.

The mean Outdegree for faculty across the network was 2.3 connections (SD = 2.1), and the mean Indegree was 1.5 (SD = 1.4) . This implies that, on average, Faculty surveyed are assisted by two or three with their teaching, and in turn, provide assistance to one or two, but there is high variability. Over 1/3 of the sample had no colleagues in the social network with whom they interacted for the purposes of improving instruction, but some (BIO15 and FRESH3, for example) have many connections—their Indegree is especially high (5 each). These two faculty serve, in their respective departments, as instructional leaders, sharing practices and materials with their colleagues freely. It must be stated that degree estimates in this analysis are almost assuredly low, since we cannot claim to have sampled the entire set of colleagial connections across faculty serving first two- year engineering students at the University. Nevertheless, it does indicate that people's real contact for their own professional development is severely curtailed, given the University employs over 700 faculty in the surveyed departments.

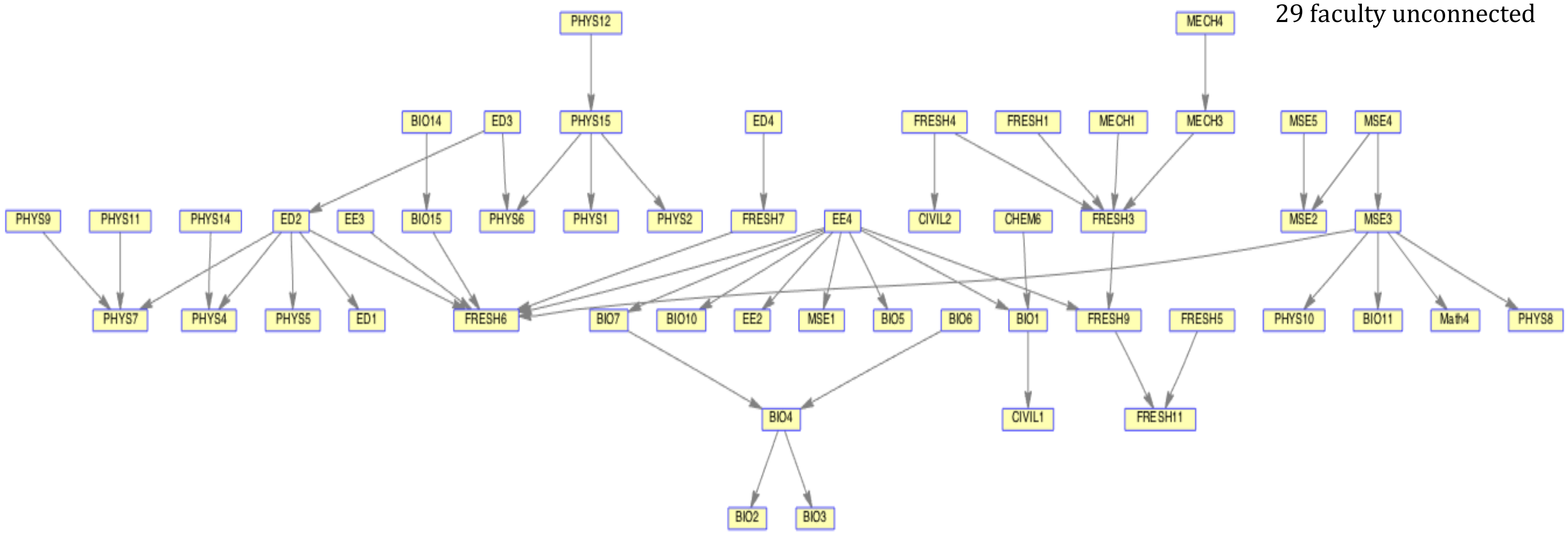
Table 1 presents the mean Outdegree and Indegree of each department.

Table 1. Mean Outdegree and Indegree Across Participating Faculty Departments

	Bio	Chem	Civil	Comp. Sys.	Educ.	Elect.	Fresh.	Math	Mech/ Aero	Materials	Physics	Overall
Outdeg.	2.6	0.71	1.0	0.25	2.75	2.4	5.4	1.5	1	3.33	1.85	2.3
Indeg.	1.6	0.57	0.5	0.00	1.25	1.4	3.3	0.25	1	2.17	1.38	1.5

Figure 2 presents the minimal spanning tree for the faculty network. A minimal spanning tree is a graph that connects all the nodes together, accounting for direction of flow, with a minimum number of edges. A quick look shows that at most, the depth of the tree, beginning at any single faculty member is at most 5 (beginning at MECH4, a Mechanical/Aerospace faculty member), and averages between 1 and 2 colleagues. This shallow depth, coupled with the fact that 29 of 80 participants could not be connected in the tree illustrate that it is *impossible* to reach all faculty members (say were the University to design a professional development program aimed at

Figure 2. Minimal Spanning Tree of the Faculty Social Network



improving faculty teaching practice at scale) given current, “natural,” relationships. Some means of providing institutional pressure or support to connect faculty across departments is critical if instruction is to improve in an expanding community of practice

Relationship Between Faculty Connectedness and Learner-Centered Attitudes and Practice

Table 2. Pearson Correlations between degree of connectedness and dimensions of Faculty Learner-Centered Attitudes (ATI) and classroom practice (RTOP).

	1	2	3	4	5	6	7	8	9	10	11	12
OutDeg.	.059	.270	-.351	-.290	.212	-.367	**.528***	.020	**.453***	.347	.277	.420
InDeg.	.277	.395	-.140	-.106	.400	-.142	**.617****	.053	**.555***	.393	.408	**.490***

*p<.05
**p<.01
ATI Dimensions: 1. Conceptual Change Intention, 2. Student-Focused Strategies, 3. Information Transmission, 4. Teacher Focused Strategies, 5. Conceptual Change/Student Focus composite, 6. Information Transmission/Teacher Focus composite.
RTOP Dimensions: 7. Lesson Design and Implementation, 8. Propositional Knowledge, 9. Procedural Knowledge, 10. Communicative Interactions, 11. Student/Teacher Relationship, and 12. RTOP composite.

To test the hypothesis that more connected faculty, on average, engage in more learner-centered practices, scores on the ATI beliefs instrument and RTOP observational instrument were correlated with degree of connectivitiy for each participant (see Table 2). As can be seen, correlations are low to moderate across most dimensions of learner-centered faculty beliefs, and classroom practice. The direction of relationships are all in the expected direction, indicating a positive relationship between connectedness and learner-centeredness in general, and a negative relationship betweeen connectedness and teacher-centeredness. RTOP scores were generally very strongly related to connectedness, with *lesson design and implementation* showing the strongest relationship. This dimension focused on strategies that account for students’ prior knowledge, engagement of students as members of a learning community, encouragement of alternative modes of investigation and problem solving, and using students ideas to help direct the lesson. The second highest correlation centered on procedural knowledge, a dimension emphasizing rigor of ideas, multiple representations, and engagment in hypothesis building and testing. The least correlation centered on *propositional knowledge.* This dimension focused on the subject matter knowledge of the teacher, the abstractness of the content, connections to other disciplines, and the coherence of the conceptual understanding promoted by the lesson.

It is also important to note that none of the ATI dimensions were significantly correlated with connecteness. While technically this indicates no systematic relation between the variables, the relatively small number of particpants in the study yields relatively low power. With an earlier study showing significant positive relationships between ATI and RTOP scales, we feel there is still merit in reporting these correlations as consistent with theory. However, it is the overall pattern of the relationship, not each individual correlation that should be examined.

Discussion

In the context of large-scale reform of first-two years' STEM teaching practice at a major research University, the present study shows that faculty isolation is a quantifiable phenomenon. Moreover, the *quantity*, if you will of instructors' interconnectedness related to sharing teaching practices is significantly related to their knowledge of, and ability to implement learner centered practices in their beginning courses for engineering majors. Relatively strongly correlations to learner-centered practices is especially important, since those practices are the key to change in the experiences freshman and sophomore students that might improve their learning and understanding of foundational concepts and skills, *and* their enjoyment and satisfaction with these courses as indicative of their future success in their engineering major. This latter supposition, of course, was not tested in the present study. This is necessary future work.

Our findings echo those by Judson & Lawson, who found that the indegree of high school STEM teachers' social networks related strongly, at about the same magnitude as the present study, with their RTOP scores. These were interpreted as indicative that constructivist teaching practices, a close analog to learner centered practices, are highly related to the degree to which teachers are seen as resources by their colleagues.[8]

The authors report that, in a social network, the degree to which an individual is seen as a resource, where their colleagues come to them for assistance, is an indication of their leadership. Moreover, the number of people in a network with large indegree indices is a good measure of closeness of collaboration. Friedkin & Slater suggest that such sources of advice and creativity can be more influential in the social network than more fomal leadership roles.[13] We also found this to be the case, with Bioengineering, Freshman Engineering and Physics especially, having closer within-department relationships. Moreover, these departments show extensive support in terms of funded projects, professional development, team meetings and official repositories of faculty teaching materials by which their intra-departmental teaching culture can flourish. Mathematics, Chemistry, and Computer Systems Engineering showed markedly fewer intra-departmental connections, and markedly less explicit support for improvement of instruction.

The sparseness of the minimal spanning tree for the network is additionally concerning: Current faculty relationships, being primarily intra-departmental, and shallow (averaging fewer than 2 degrees of separation) prevent large scale propagation of teaching innovations without significant investment in forging inter-departmental collaboration. The few faculty members with large Indegree, might serve, in this case, as important brokers of innovation. As acknowledged leaders in their informal in-department network, they might be recruited as ideal candidates for sharing their innovations across departments, given administrative and fiscal support.

In summary, the research reported in this paper provide further evidence that faculty culture is moderately to strongly related to quality practice—at least as a mediating variable for learner centered instruction. Faculty with more connected social networks displayed higher scores on conceptual change and student focused attitudes, and lower scores on information transmission and teacher focused attitudes, than faculty with fewer connections. Moreover, faculty with larger social networks scored highly on all learner-centered variables with the exception of the propositional knowledge subscale on the RTOP. Some caution must be urged here. None of the correlations for faculty attitudes were statistically significant. However, the strong correlations for faculty practice variables lends support for our original hypothesis. Moreover, it cannot be assumed that the patterns of relationships found in this study would reflect the patterns at another university with different departmental structures, support for teaching, and faculty roles and responsibilities. Nevertheless, it does provide some indication that natural affiliations among faculty may not be adequate for effective diffusion of innovation in teaching practices at scale, and that there is a likelihood for interdepartmental isolation of faculty teaching first two-years courses.

Future research must assess the extent to which these key components of a faculty community of practice impact student outcomes, including student learning, success, and retention in the major. Additionally, the extent to which natural brokers (those with large Indegree) can be recruited to strengthen faculty connections within and across departments is a potentially powerful testable hypothesis for the improvement of first two-years engineering instruction.

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