2018 ASEE Annual Conference & Exposition
June 24-27, 2018
Salt Palace Convention Center
Salt Lake City, UT

Paper ID #21975

Social Network Analysis of Faculty Connections in a Multi-year Professional Development Program

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Social Network Analysis of Faculty Connections in a Multi-Year Professional Development Program

Arizona State University

Abstract

This research paper examined the connectedness of Engineering faculty, teaching first and second year courses, to others both within and across academic departments who might be potential resources for diffusion of Learner-centered practices. In particular, the relationship of participants' social networks on their teaching practice was studied as an outcome of a year of professional development wherein participants were organized into disciplinary working groups, met regularly to discuss and implement learner-centered practices. The research question under investigation was: to what extent did the professional development activities improve the social network of faculty in the institution, and to what extent did this improvement influence faculty instructional practices? The connectedness of faculty in the network was assessed using Social Network Analysis (SNA). Participants recorded the faculty with whom they approached for help in learning about to improve their teaching, and also those faculty who approached *them* to solicit their help in improving teaching. Results show that the number and depth of connections in the faculty network deepened and extended dramatically. Moreover, there is evidence that the degree of connectedness as influenced by the professional development experiences is associated with an increased rate of change in faculty learner-centered teaching practices. Results are discussed regarding the importance of creating professional communities of faculty who regularly meet, try out new teaching behaviors, and share their experiences for the wide-scale improvement of first and second-year engineering programs.

Introduction

This study reports on a follow-up administration of a multi-wave Social Network Analysis (SNA) of faculty engaged in teaching courses in the first two years of undergraduate engineering programs at a major research university. Participating faculty were engaged as departmental cohorts in an intensive professional development program focused on learner-centered, strategies, specifically strategies associated with Active Learning. The research question under investigation was: to what extent did the professional development activities improve the social network of faculty in the institution, and to what extent did this improvement influence faculty instructional practices?

Networks are important models for understanding both how to *think* about diverse organizations of human beings, and to *organize* human beings into more optimal, collaboratively functioning systems [1]. This approach, rather than focusing on the individual attributes of group members, instead models the ways in which individuals share information one with another, the flow of that information, and the boundaries and limits of the information exchange. Yet within any social network, certain individuals do exert influence. Such people are termed, "bridges," or "brokers" if they span subgraphs in the larger network, allowing flow of information across previously isolated groups. Social network analysis (SNA) enables brokers and other key players to be identified and the structure of the network to be empirically described and graphed visually, and analyzed empirically. Network analysis can provide information on such processes as communication flows and bottlenecks, which in turn may suggest interventions to enhance function [2].

In an earlier paper) we reported on the results of a large scale SNA involving 81 faculty participants from Physics, Chemistry, Mathematics, and Teacher Education departments, and from six other departments in the College of Engineering. That study showed that the number of connections a particular faculty member had (in particular in-degree, the extent to which faculty members are seen as sources of information and support) was positively related to more positive learner-centered attitudes, and practices as measured by the Attitudes Toward Engineering scale and the Reformed Teaching Observation Protocol, respectively. There were significant differences in the extent and connectedness of faculty across departments, reflecting departmental instructional climate [3].

In this follow-up, we examine the social networks of faculty, many of whom were not included in the original sample, who were recruited to participate in a 1-year series of workshops on learner-centered pedagogy, active learning methods, and use of advanced instructional technology and assessment. Forty-three faculty participated in eight professional development workshops (approximately one every two weeks for each of the two semesters in Fall, 2016 and Spring, 2017) on Evidence Based Instructional Practices (EBIS). Faculty were asked to implement one or two new teaching practices and reflect on their efficacy in between sessions. In subsequent sessions, faculty were provided time to reflect with each other, share their experiences, and get assistance from experienced educators.

How *can* a university exploit the social networks of faculty teaching first-year engineers to create impactful professional development program? Engineering education and the STEM education literature more broadly, is replete with studies that show that faculty tend to be isolated, and that one key to improving instruction at the departmental scale is to provide opportunities for faculty to collaborate together on improvement of their own practice [4] [5] [6].

This is important because recent research by Oleson & Hora, shows that faculty, contrary to stereotype, do not just teach the way they were taught, but have a variety of influences on their instructional style. Influences included their prior experiences as students, but instructors reported that professional development strongly informed their knowledge base and the kinds of activities and tools they attempt to implement. These professional development activities included workshops, becoming involved in working groups studying teaching, reading pedagogical research, and individualized feedback from others [7].

The professional development experiences in the current study utilize each of these dimensions: Faculty participated in 14 bi-weekly sessions focused on the best available research on student learning, motivation, and the technologies and practices that support productive student engagement in STEM. Additionally, they were organized into disciplinary teams tasked to meet together and discuss the fits-and-starts of trying out new pedagogical approaches. Readings were assigned for each session to support faculty learning and to provide a rigorous empirical basis for implementing learner-centered practices. And finally, faculty were observed using the Reformed Teaching Observation Protocol, and provided feedback from an expert observer, regarding their practice. Together, these dimensions were hypothesized to improve faculty collaboration, and over time, improve their instruction in first year courses [8].

Research Question

This study provides confirmation that support networks of faculty can be fruitfully developed. Because our earlier work shows faculty being isolated even within departments, the current study utilized departmental structure and curriculum as a natural means of connecting instructors in meaningful analysis of the tasks, tools, and teaching behaviors they enact in first year classes. Both the number of connections among faculty and the direction of faculty influence were studied.

Specifically, we asked the question, "To what extent did the professional development activities improve the social network of faculty in the institution, and to what extent did this improvement influence teachers' practices?

Method

Participants

Our initial cohort (reported in 2016) consisted of 80 faculty 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. Snowball sampling, wherein an initial group of 21 randomly-selected instructors identified the faculty with which they had had conversations about teaching. These additional faculty were added to the database, bringing the total to 80. Snowball sampling is useful in this context because it starts with an unbiased sample (the initial 21), and then gathers the most important nodes in each faculty member's personal network, from the participants themselves, and therefore is a more complete sampling procedure than random sampling from among hundreds of faculty across departments, who may or may not be connected to each other.

The degree of overlap among each faculty's network, therefore, is an index of both within and cross-departmental communication patterns. In the 2016 study, each member of the entire network of faculty selected from the list of members, those faculty with whom they communicated regarding improving instructional practice, curriculum, and technology integration. The result is a mapping that is representative of the communication patterns among first-year faculty in engineering programs, across departments.

In the present study, we added to this database by selecting an additional 60 faculty across six engineering departments who were identified by their department chair to participate in the professional development program, bringing the database of potential faculty up to 140. These faculty were provided a small stipend for their time: $1,200 per person, prorated by the number of sessions attended. The study reported in this paper focused on this expanded network, and especially on the 43 faculty who completed the professional program. Due to some attrition, and incomplete data for some variables, various analyses will have smaller sample sizes.

RTOP

For the cohort of 43 instructors, we attempted to schedule multiple observations in both the Fall, 2016 and Spring, 2017 semesters. Thirty-five instructors were observed at least one time, and 26 were observed at least 4 of the six scheduled observations. In the present study, we eliminated from analysis, any instructor who did not have at least 4 class sessions observed leaving 26 who's growth curves on the Reformed Teaching Observation Protocol could be estimated.

The Reformed Teaching Observation Protocol (RTOP) was used after each observation to code teaching practices associated with learner-centered teaching. The RTOP is a classroom observational protocol that quantitatively characterizes the extent to which faculty implement learner-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 [9]. In this study, we use the overall score over time as the dependent measure.

Social Network Analysis

Social Network Analysis is a set of analysis techniques that uses graph theory to model the connectedness of people. It maps the connections between people, in this case, keeping track of the direction of communication among faculty members. We follow the method of Judson & Lawson who used this method fruitfully to predict the relationship between high school STEM teacher connectedness and dimensions of the RTOP [10].

To solicit faculty connections, we created a survey in Qualtrics that paired each respondent with a list of the other faculty in the database. Each participant was asked to check a box indicating whether they "go to" each colleague in the list of 140 to share teaching strategies (to measure out-degree, the extent to which communication flows from the responding faculty member to another), and then asked to check a box whether each faculty member "comes to" them to share teaching strategies (to measure in-degree, the extent to which communication flows from another faculty member *to* the respondent). Both in-degree and out-degree were accounted for, enabling the results to be analyzed as a directed graph.

Results

Social Network Analysis

Overall results show that, like faculty in the original study, many participants continued to be very isolated. For the 140 faculty for which we have data, both in-degree and out-degree averaged less than 2 connections, though there was considerable departmental variability. In particular, new faculty, on the tenure-track, showed extreme isolation regarding improving their instruction with some exceptions attributable to departmental culture. However, when one examines the graph of just the faculty involved in the professional development program, a different picture (literally) emerges.

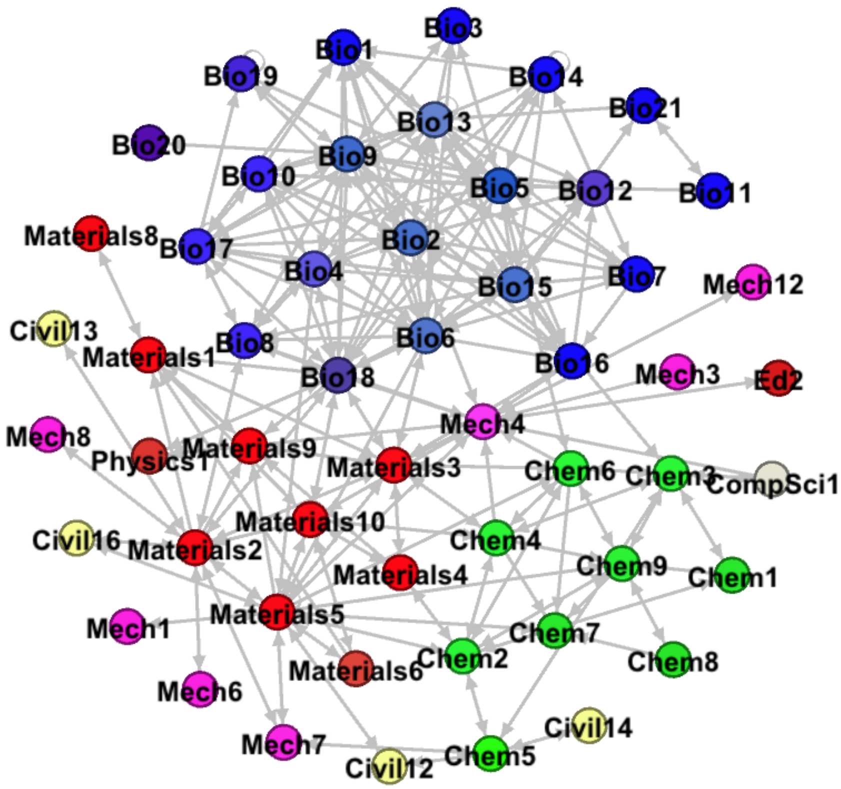

Figure 1. Directed Graph of Faculty engaged in professional development activities in 2016/2017.

Recall in [3], the mean number of connections among faculty in the broader network was less than, or right around 2, similar to the larger network of 140 faculty in the present study. For those faculty who engaged in the professional development program, however, the average number of connections reported was a whopping 6.22. This can be interpreted to mean that a typical faculty member who participated actively in the program engaged with a bit over 6 other faculty members in matters related to improving their instruction.

Figure 1 also shows clearly the pattern of how disciplinary faculty in the professional development program tend to cluster together when engaged in discussions of how to improve their teaching (direction of communication is indicated by the direction of arrows connecting nodes in the graph). The density of connections among faculty *within* disciplines is much greater than the density among faculty *between* disciplines. This is true for even more sparsely populated networks for Mechanical and Civil Engineering faculty. The sparseness of these sub-networks can be seen by the fact that each faculty member (e.g., Mech 6) is connected to few others.

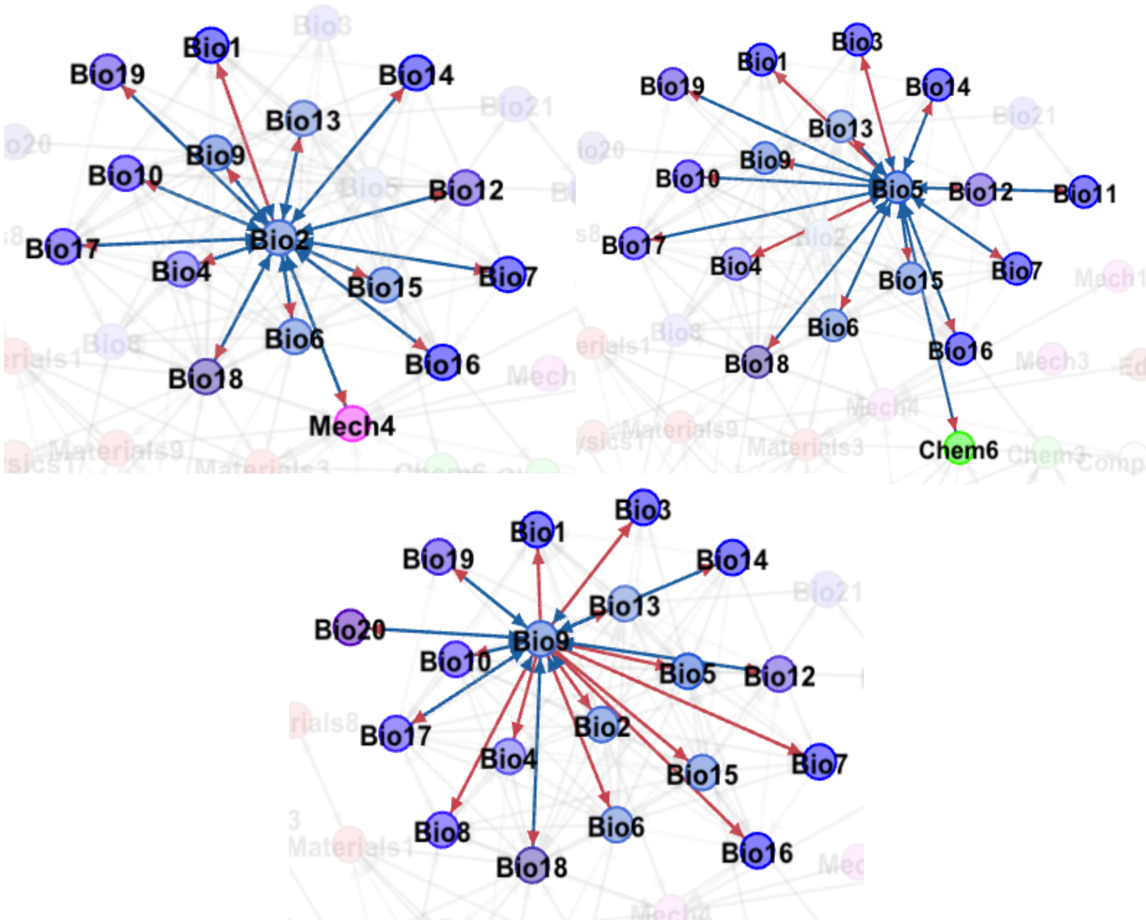

Figure 2. Networks of Three Faculty Representing High Degree of Connectivity

The within-department connectivity is illustrated well in Figure 2 showing the networks of the three most connected people in Bioengineering. These three faculty: Bio2 (In-degree 15, Out-degree 15), Bio5 (In-degree 17, Out-degree 17) and Bio9 (In-degree 13, Out-degree 18) each show high connectedness, but the relative balance in the direction of their connections shows that interactions are *collaborative*. That is, as their colleagues are both contributing to, and benefitting from the learning of these faculty in the program.

This is, we feel, indicative of the approach taken in the design and conduct of the professional development program. Faculty were organized into sessions with others in their department who often taught the same courses, or taught complementary courses in the curriculum. In this manner, objectives for each course, examples and tasks designed could be shared and used more readily without having to adapt to new content and objectives. But it is also reflective of the departmental culture we studied in our earlier paper. In that study, we found bioengineering in particular to have more connections within its faculty, and more learner-centered teaching practices evidenced. In general, across the larger network, while some faculty met with others across departments because of scheduling, for the most part, faculty stayed with their own.

But this was not entirely the rule. Other faculty appear to be *Brokers* across disciplines. Mech4, for example has In-degree of 14, and Out-degree of only 8, indicating that s/he is approached by their colleagues nearly twice as much as s/he looks to their colleague for help in teaching practice. This is a typical *Source* pattern of someone who has expertise to give.

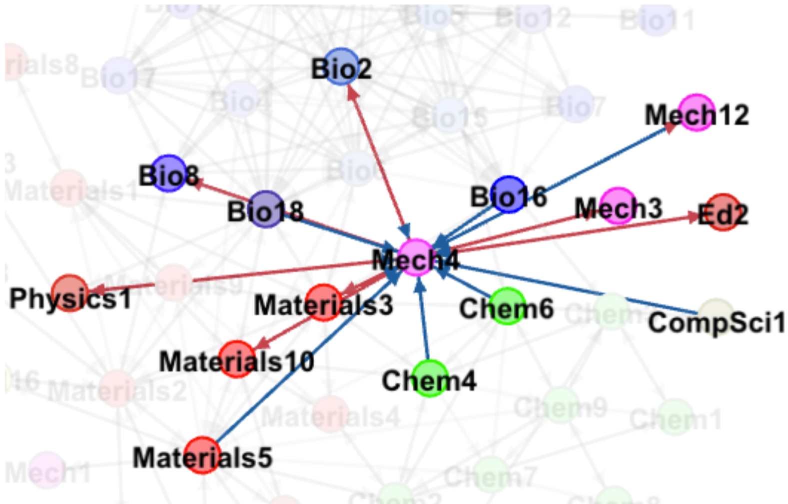

Figure 3. Network of a *Source* Broker across Departments

Materials5, on the other hand, with In-degree of 12 and Out-degree of 15, approaches others more often than s/he is approached (See Figure 4). This is an example of a *Sink* Broker, one who gathers information from a variety of sources outside her/his home department. But this faculty member also has a relatively high In-degree, showing that s/he is also an influence across departmental lines.

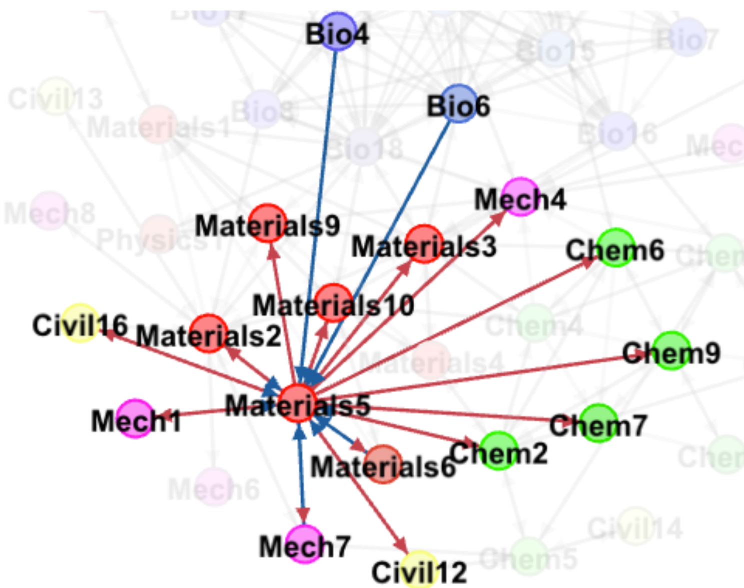

Figure 4. Network of a *Sink* Broker across Departments

Such brokers are critical for the diffusion of innovation as they provide validation of the efficacy of new strategies independent of the school's administration or the faculty champions who lead the professional development. In essence, such brokers represent proofs, in the eyes of participants, that the innovation can be successful, and their experiences can be used as models for the implementation of practices that they found successful (e.g., being individuals that serve a similar role as *innovation brokers* in institutional networks [11]).
In summary, Social Network Analysis of the faculty participants in the program supports the hypothesis that engaging faculty in disciplinary workshops designed to provide information and discussion of best practices for active, learner-centered teaching *does* create a different kind of social network, one with more and deeper faculty connections for the majority of participants than those left to their own trial-and-error attempts.

But the question remains, to what extent is this expanded network facilitative of *improvement* in teaching quality, as it pertains to a learner-centered approach?

Regression Analyses

In an attempt to answer this question, a repeated measures analysis of variance was conducted with RTOP administration as the repeated-measure dependent variable, and degree of connectedness as the independent variable. In-degree and Out-degree were collapsed into a single measure, Degree, listing the total number of people any participant either approached or who approached them for the purposes of improving instruction. This was done because the large majority of faculty in the participant cohort reported the same In-degree as Out-degree. This is at least partly due to the design of the workshops involving discussion and collaborative interaction, but it may also be a partial artifact of a social desirability effect in the Qualtrix survey acting as a biasing factor.

An additional problem we faced was twofold: First, there were few participants who were observed more than twice. Any individual observation of practice can be highly variable. In the administration guide for the instrument, it is advised to use at least three observations to gain stable measurement. For this reason, we eliminated from the analyses, any faculty member who had fewer than 4 of the 6 scheduled observations. This left 26 faculty, 4 of which had one missing observation. For those, we use a mean substitution for the missing observation. This had a tendency for a positive bias in overall intercept for individual growth curves for these 4 participants, and a negative bias on the slope of the individual's growth curve (more missing data occurred around the end of the Fall, 2016/beginning of the Spring, 2017 semester, and most faculty improved overall in the year, see below).

Additionally, because so many of the faculty in this reduced sample had low connectivity (0, 1, 2 connections), we created three qualitative classes of connectivity: Low, Medium, and High. Instructors with Low Connectivity had 0, 1, or 2 connections. Those with Medium Connectivity had 2 to 5 connections, and those with High Connectivity had the mean number in the cohort, 6 or greater connections.

Figure 5 is a scatterplot showing the growth curves for these three levels of connectivity: Low, Medium, and High, denoted by color.

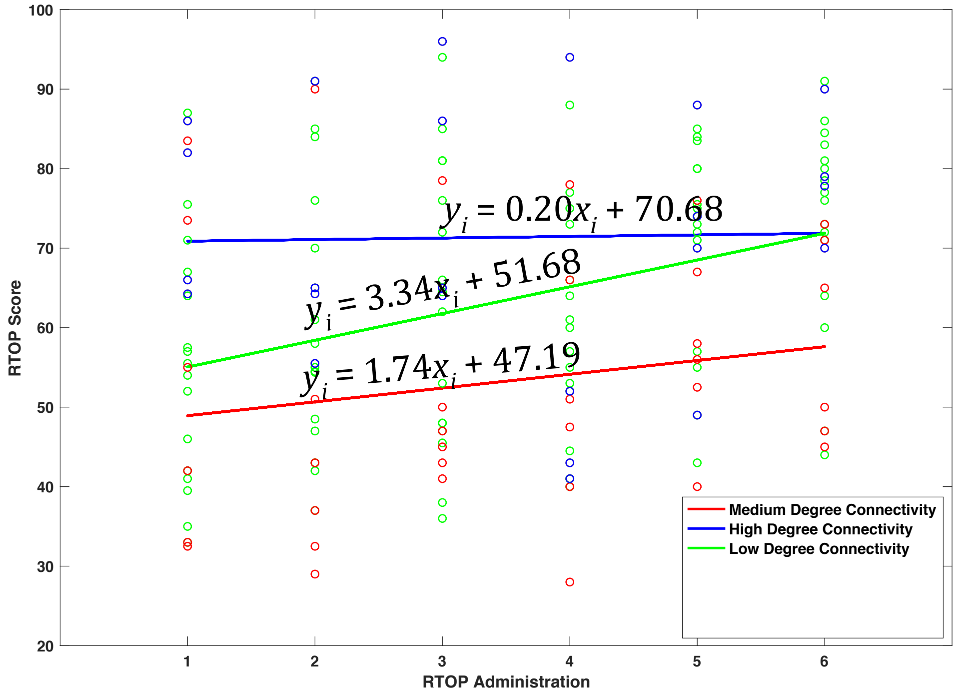

Figure 5. RTOP Score by Administration. Administrations 1 and 2 are from Fall, 2016, and Administrations 3, 4, 5, and 6, are from Spring, 2017.

Examination of these growth curves shows that those with a high number connections at the beginning of the study, also had high RTOP scores. Those with Medium and Low connectivity had lower initial scores (i.e., less learner-centered practices). But over time, as one would predict, those with lower connectivity, when engaged with others in the professional development program, improved significantly in their teaching practice. Those with High Connectivity remained almost static overall. It must also be noted that there is considerable variation in individuals' scores over time, and considerable variation for each level of connectivity within each administration:

$$\bar{X}_{Low} = 19.6,\ s_{Low} = 23.40$$
$$\bar{X}_{Med} = 4.33,\ s_{Med} = 12.92$$
$$\bar{X}_{High} = 4.31,\ s_{High} = 8.38$$

Table 1 provides the linear contrast ANOVA results. It shows that there is a clear improvement in teaching practices over time for all participants in the analysis. It also shows some support for a linear interaction between connectivity and RTOP administration over time. Unfortunately, with only 5 participants representing highly connected faculty in this reduced sample, the power to detect a significant difference is just not there.

Table 1. Linear Contrasts for RTOP Scores Over Time (Repeated Measures) and Connectivity

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Time	1171.911	1	1171.911	6.700	.016
Time x Connectivity	900.827	2	450.414	2.575	.098
Error(Time)	4023.200	23	174.922		

Because the variability across RTOP administrations was high (see Table 1), and because the variances across connectivity groups was decidedly unequal and thus violate the assumptions of the Analysis of Variance and other asymptotic regression procedures (further reducing power), we collapsed the Medium and High Connectivity groups into a single group: High(er) Connectivity, to compare with the Low Connectivity group. Gain scores on the RTOP were computed using the initial observation in Fall, 2016, and the final observation in Spring, 2017. We then had two groups by which we could then compare gains.

Ordinarily Student's t-test would be used for such a design, but the variances of the two groups are widely different, violating its assumptions, significantly decreasing power of the analysis. To ameliorate this, we generated a boostrapped sampling distribution of the gain scores for each group. This yielded two vectors, representing the long-haul behavior of samples, all of the same size as the original groups, taken from populations centered on the group means, with score characteristics assumed to be well-represented by the groups.

Subtracting the two vectors yields a vector of differences of randomly drawn samples, High Connectivity minus Low Connectivity. *This* vector can be thought of as the sampling distribution of the differences in means of samples all drawn from their respective populations. Under the null hypothesis, these differences should average to zero by the Central Limit Theorem. With this vector, we computed the 95% confidence interval of the mean difference, and found it to be (2.15, 27.97) [12]. Since the mean difference expected under the null hypothesis (0) is well outside this interval, we can conclude that there is a significant difference in RTOP gain scores for Faculty with Low Connectivity versus High(er) Connectivity:

$$\bar{X}_{Low} = 19.6,\ s_{Low} = 23.40$$
$$\bar{X}_{High} = 4.80,\ s_{High} = 10.56$$

This provides confirming evidence that faculty with Low initial connectivity benefitted more from professional development, as evidenced by their teaching practice.

In summary, the professional development can be deemed effective in promoting the improvement of learner-centered teaching practices and for improving faculty connectivity related to the improvement of instruction. There is good initial evidence that these two are linked causally, but a greater number of participants with complete data is necessary to make this case more rigorously.

Discussion

Our current data show that the social networks for faculty, *when the University incentivizes and structures professional development*, grow both within and across departments. Moreover, participation in professional development, and reflection with colleagues regarding one's own teaching practice positively influenced faculty to implement learner-centered pedagogy resulting in higher scores on the RTOP.

It is no surprise that providing some special funding to compensate faculty for their time to learn about and implement engagement teaching practices increased their interactions with each other, but this represents a near tripling of the effect in a short period of time: From 1 or 2 connections to an average of over 6 in one academic year and 14 sessions is noteworthy. While the evidence is not yet at a rigorous standard to say that these faculty networks are causal, at least partially, in supporting faculty risk-taking and reflection, we think there is merit to the hypothesis given the patterns of within department connections, the bi-directionality of those connections, and the evidence that shows that the professional development was effective in supporting change.

This study, and others show that one key strategy to the improvement of first years' programs is to seed and support faculty communities, communities of practice if you will, gathered together to learn, share, implement, and reflect on the improvement of teaching. In the present study, we focused on disciplinary organization. This proved to be useful and effective, however, there is scarce evidence that this is a *better* organizational scheme than cross-disciplinary cohorts. This is important in that while a supportive social system appears to be in place in at least one department in the current study, other work shows that some departmental cultures constrain individual faculty from going too far out of bounds in their instruction, and that some kind of collaborative effort both within and between departments that impact freshman success in engineering, is warranted [13]. More research on effective organization of learning communities is certainly needed.

With regards to the ongoing effort, we are continuing to engage faculty in a second year of professional development, and the comparison with, and extension upon, the current study will provide a more robust accounting for what aspects of faculty relationships seem to be supportive, what aspects are neutral, and what, if any, might be detrimental to collaboration and systematic improvement of practice.

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