Understanding the Roles of Professors of Teaching in Departmental and Institutional Networks about Teaching

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Working Paper #21-8

UCI Education Research Initiative

VERSION: December 2021

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Abstract

The need to improve postsecondary instruction is being met by a growing number of change initiatives across the globe, and teaching-intensive academic positions have seen increased international importance. One institutional strategy for instructional change has been hiring faculty with pedagogical expertise into traditional disciplinary departments, who may then help improve instructional practices of their colleagues. This strategy has been adopted across the University of California (UC) system in the United States, where pedagogically focused faculty lines have been created across a number of UC campuses and departments, referred to here as 'Professors of Teaching' (PoT). We examine the potential impact of this specialized position may be having on their colleagues' pedagogy by studying their role in departmental and institutional networks. We primarily focus on their role in discussions about teaching and in providing advice about teaching. Social network surveys were sent to 577 faculty across 19 departments in three campuses, including 34 PoT faculty. Compared to non-PoT faculty, PoTs discuss teaching with and provide advice about teaching to significantly more colleagues than non-PoT peers. This was found in interactions that occur between faculty in the same department as well as interactions among faculty from different departments, where this propensity was particularly strong. The position of PoTs within their departments was central enough to significantly alter the larger discussion network structure of their departments when compared to the role of non-PoT faculty. Our results suggest that PoTs play roles as local experts to non-PoT colleagues within their department while simultaneously providing a means for information about teaching to transmit between departments.

Introduction

It is well established that instructional practices can be transformed to improve undergraduate science, technology, engineering, and mathematics (STEM) education (S. Freeman et al., 2014; Theobald et al., 2020). Despite this evidence, the most common form of instruction continues to be traditional, didactic lecture (Stains et al., 2018). This situation has triggered international calls for reform alongside a growing body of research and work aimed at achieving this reform (Henderson et al., 2011, 2018; Kezar, 2018; Science, 2019). One strategy for transforming undergraduate STEM education is to embed faculty with pedagogical expertise into academic departments (Bush et al., 2008; Rawn & Fox, 2018).

As higher education changes to meet growing demands, teaching-intensive positions have seen increased international importance. As of 2015-16, 26.1% of individuals in academic positions in the United Kingdom were in teaching-only positions (HESA, 2018). In Australia, the growth of teaching-only positions between 2010 and 2019 outpaced that of positions with research expectations (Department of Education and Training, 2020; Rogers & Swain, 2021). Canadian institutions have similarly experienced a rise in the number and importance of teaching-focused faculty (Rawn & Fox, 2018; Vajoczki et al., 2011), as has the United States, where faculty in non-tenure positions make up a majority of instructors in higher education (Kezar & Maxey, 2013).

While many of these are contingent positions, a growth of tenure-eligible faculty positions focused on pedagogy have emerged in the US. Faculty in these positions are meant to do more than fill a university's teaching needs. They are also tasked with enhancing teaching quality and student learning experiences (Probert, 2013),

professionalizing and stabilizing the higher education teaching force (Ontario Confederation of University Faculty Associations (OCUFA), 2008), and in many cases, engage in education research. One example is discipline-based education research (DBER) positions, which include research and teaching expectations in line with traditional research-focused faculty within their departments (Dolan et al., 2018). Science faculty with education specialties (SFES) are another example of a pedagogy focused position in the US. SFES represent a highly heterogeneous group of self-identified individuals who share a focus on science education. Faculty in these positions vary in whether or not their position is tenure-track and whether their expertise is in K-12 science education or undergraduate education (Bush et al., 2008, 2011).

More recently, the University of California (UC) system in the United States has started to hire a new tenure-track teaching-intensive position, which we refer to here as Professors of Teaching (PoT)[1]. The PoT faculty line is a standardized position with expectations centrally outlined in the UC Academic Personnel Manual (University of California Office of the President, 2018). This tenure-track position has similar merit and promotion reviews to tenure-track research-focused faculty, progressing through the ranks from Assistant PoT to Associate PoT and full PoT ranks. The main difference between PoT and traditional research-focused tenure-track positions is in the outlined expectations; although PoTs are principally trained within a STEM discipline, they are expected to spend about two-thirds of their time on teaching (Harlow et al., 2020). This is reflected in the evaluation of PoTs, which emphasizes teaching excellence alongside less emphasized expectations for scholarship and service. Teaching excellence for

[1] The UC system created this position under the designation Lecturer with Security of Employment. However, the working title for this position varies across UC campuses, such as Teaching Professor and Professor of Teaching. For simplicity, we will use one of the working titles Professor of Teaching and the acronym PoT throughout this paper.

PoTs is broadly defined to include the quality of their own instruction, leadership in educational initiatives, and professional development for colleagues in their departments, etc. (Harlow et al., 2020b). Scholarship for PoTs can encompass a wide range of activities such as discipline-specific research, discipline-based education research (DBER), educational outreach to primary and secondary settings, and curriculum development at the undergraduate level (Harlow et al., 2020a). Service takes up about 15% of PoT's time and is often related to the educational mission of their departments and campuses (Harlow et al., 2020a).

Research on PoTs suggests that this group of academics is driving change. Faculty in these positions have greater pedagogical expertise than colleagues in traditional research-focused roles, which has resulted in improved pedagogy within their institution. (Harlow et al., 2020) Beyond implementing evidence-based instructional practices (EBIPs) in their own classrooms, these types of faculty may also spread pedagogical innovations through their departments by engaging colleagues in changing their instructional practices (Andrews et al., 2016; Bush et al., 2016, 2019; Harlow et al., 2021). Therefore, it is important to explore the roles of PoTs in departmental and institutional networks about teaching in order to examine their potentials for promoting pedagogical change in higher education.

Four Frames model for organizational change

Here, we examine the potential for PoTs to transform pedagogy within their institutions. In doing so, we view this position through the lens of the Four Frames model for organizational change (Bolman & Deal, 1991). This widely adopted framework considers structures, symbols, people, and power as cornerstones that must all be

engaged to successfully achieve organizational reform. This framework was recently adapted for thinking about change in higher education, with a central focus on reforming departmental culture (Reinholz & Apkarian, 2018). Here, departmental culture is defined as an evolving set of *structures* and *symbols*, which are embedded in historical contexts that result in *power* relationships between *people* involved in departmental decision-making processes (Reinholz & Apkarian, 2018). Organizational structures refer to formal positions, such as teaching-focused academic positions with specified roles, responsibilities, and incentives, that contribute to the change process. Cultural symbols represent the often implicit ways of thinking that inform how the organizational structures operate, and these symbols can include documents, language, knowledge, vision, and values. People as a frame centers individual agency and identity and highlights how different individuals may engage with the same departmental change process differently. Power comes in the form of asymmetric relationships, which can arise via differences in social or professional identities, thus contributing to the present structures and symbols in a department.

In examining the role PoTs play in institutional change, we consider the creation and utilization of PoT positions as representing institutional change efforts that may precipitate larger changes to the organizational culture. While our focus on PoTs remains within the structural frame, it is important to note that symbols, people, and power are all interconnected with organizational structures in the Four Frames framework. This becomes apparent when considering how features of the PoT position that distinguish it from other faculty positions are also likely to be important for faculty in these roles to enact meaningful change. For example, having a formalized role that

includes standardized expectations and a title that denotes expertise reflects institutional recognition of the intended expertise among faculty in these positions. Though this unique identity may introduce some risk of isolation within their own department, the fact that many departments have hired multiple PoTs means that many faculty PoT positions will be in proximity to colleagues with shared professional identities and academic interests. This built-in social support can be critical for employee well-being and success (Ko, 2021; Voorde et al., 2012). Further, hiring PoTs in concert amplifies the human resources within departments and institutions needed to help drive change.

To date, research on PoTs suggests that this structure is driving change. Faculty in these positions have greater pedagogical expertise than colleagues in more traditional research-focused roles, which has resulted in improved pedagogy within their institution. For example, a majority of PoTs report familiarity with EBIPs (Harlow et al., 2020), though the long term outcomes of students in courses taught by PoTs do not appear to be drastically different than students taught by traditional research-focused faculty (Xu & Solanki, 2020).

These individual-level measures of teaching success are important, but they are not the only ways in which PoTs may be influencing undergraduate education. As part of their department and institutional communities, PoTs may also be helping reform their colleagues' pedagogy. Indeed, campus administrators have indicated that PoTs serve as educational experts who help improve the teaching practices of their colleagues (Harlow et al., 2021). This observation is promising, especially when one considers that the potential for reform through interpersonal influence can be much greater than reform

that occurs because of one's own teaching practices. This potential can be quantified by capturing the number and types of colleagues PoTs interact with about teaching. Here, we provide a more comprehensive understanding of the potential impacts PoTs have on pedagogy at their institutions by assessing the role PoTs play within their organizational social networks.

Social network analysis (SNA)

SNA provides an appropriate set of tools to examine the impact PoTs have on departmental and university discussions about teaching (Henderson et al., 2018; Quardokus & Henderson, 2015). The primary focus of SNA is on ties between actors. These ties, frequently called edges or links, can represent any association or relationship between two actors that may be of theoretical interest, such as friendships, discussions, or any other relation between two people. By embracing the importance of interpersonal ties to human behavior, and vice versa, SNA enables the ability to simultaneously study systems at the individual and group level, including the emergent properties of social systems (Wasserman & Faust, 1994).

Network perspectives are prominent in studying various aspects of higher education, including thinking about pedagogical reform and faculty change (Henderson et al., 2018; Kezar, 2014; Quardokus & Henderson, 2015). Informal discussions among faculty have been identified as important for professional development when it comes to instruction (Benbow & Lee, 2019; Wieman et al., 2010), so understanding the structure of faculty networks related to discussions about teaching can inform the change process (Quardokus & Henderson, 2015). The structural properties of a network may help promote professional development (Baker-Doyle & Yoon, 2011), or they may prevent

the transmission of evidence-based instructional practices (Lane et al., 2020). Furthermore, these networks can be used to help identify change agents (Quardokus & Henderson, 2015), study the role of faculty with educational expertise (Andrews et al., 2016), amongst other applications.

Departmental networks and faculty change

To date, most research on faculty networks has focused on single departments. The reasons for this are twofold. First, single academic departments are often viewed as an important unit for pedagogical change (Fry, 2014; Lee, 2007; Woodin et al., 2010), largely because they represent “coherent units of culture” (Reinholz & Apkarian, 2018). Thus, there is often no reason to expand the study population beyond departmental faculty. The second reason is methodological. Study populations with clearly defined memberships, like academic departments, are desirable for network census research designs (Wasserman & Faust, 1994). However, collecting relational data from an entire population with sufficient response rates is difficult, and often impossible if the boundaries of the study population are ambiguous. Academic departments are typically bounded and consist of clear memberships, making them a useful study system for SNA methods.

For departments that are hoping to reform their teaching by hiring faculty in teaching-focused academic positions, like those hiring PoTs, studying patterns in faculty discussion networks is particularly important (Andrews et al., 2016). The general idea is that the adoption of evidence-based practices may be more likely when departments have faculty with teaching expertise. This can be facilitated by interactions between research-track faculty and PoTs, where information, advice, or materials are transferred

directly from PoTs to colleagues. The extent to which this mechanism of cultural transmission occurs depends upon how well connected these specialized faculty are within their departmental networks. PoT influence can also span beyond direct ties. The presence of highly connected individuals in a network often drives larger structural changes to the overall network, which can also be important from the perspective of information dissemination and change (Quardokus & Henderson, 2015; Valente & Vega Yon, 2020). For example, the presence of one or two well connected teaching experts in a departmental network is likely to increase the overall graph-level centralization, a measure that captures how disproportionately ties are distributed across individuals in a network. Highly centralized networks can be more efficient at disseminating a unified message, leading to group-level consensus (Sueur et al., 2012), although an overly centralized network may impede certain change strategies (Gesell et al., 2013).

The importance of interdepartmental ties

While focusing on single academic departments has helped advance collective knowledge about the patterns of departmental communications about teaching, research on interdepartmental interactions about teaching remains limited. However, these ties are consequential at institutional and individual levels, and are thus important to study. Institutions may benefit from information flowing between departments by offering a means for ideas and innovations from one department to spread to others (Borgatti, 2006). This diffusion can come with refinement of ideas when they reach new contexts, or even spark new innovations (Tushman, 1977). These interdepartmental interactions can also promote better curriculum alignment between related fields, especially when prerequisite knowledge for courses offered by one department is

embedded in courses offered by a separate department. These discussions may also contribute to the growing emphasis on interdisciplinary coursework (Tripp & Shortlidge, 2019; Woodin et al., 2010) by promoting the development of courses that bring together multiple disciplines.

In addition to their importance at the institutional level, interdepartmental interactions may also be advantageous to the individual faculty involved. This point is foundational in SNA, and several different monikers have been given to actors involved in bridging otherwise disconnected groups, including boundary spanners, bridges, and brokers (Borgatti, 2006; Burt, 2004; Long et al., 2013). Actors that occupy a bridging role have potential access to novel information, and further, are positioned to leverage the flow of this information between these groups for their own personal advantage (Burt, 2009). This then elevates their importance to each group by making them important conduits of novel information. For faculty, this information could be new or unfamiliar funding opportunities, or practices and procedures that may remedy ongoing issues faced by colleagues in each group.

The role of faculty in teaching-focused academic positions

To date, little is known about the role faculty in teaching-focused academic positions play in departmental and institutional discussion networks. Given their academic identities, a reasonable assumption is that they would be preferentially sought out for advice about teaching. This was found to be the case across four departments at a single institution, where DBER faculty were more likely to share materials with colleagues and cause change to their colleague's pedagogy (Andrews et al). This greater influence was found despite the fact that DBER faculty did not have more

intradepartmental discussion partners about undergraduate teaching compared to their colleagues (Andrews et al., 2016). When given the opportunity to list colleagues outside of their department, DBERs were significantly more likely to list other colleagues, including other DBER faculty at their institution (Andrews et al., 2016).

While evidence of pedagogical reform caused by collegial interactions with DBERs at this institution is promising, whether these findings are generalizable to other teaching-focused academic positions in different institutional contexts is unclear. Compared to these other positions, the DBER position is extraordinary in how closely it resembles traditional tenure-track faculty positions, which may afford faculty in these roles greater influence amongst colleagues. In contrast, the structure of the PoT position places a greater emphasis on teaching compared to DBERs, which may increase the likelihood that non-PoT faculty see faculty in these roles as important resources for teaching advice. However, the nature of the language associated with the PoT position (e.g. “security of employment” instead of “tenure”) may diminish the power afforded to faculty in PoT positions. Further, it is unclear how generalizable the findings in Andrews et al. (2016) are to different institutional contexts, where distinct university and departmental cultures may influence the likelihood that faculty influence one another’s pedagogy. With this in mind, we investigate the intra- and interdepartmental faculty discussion networks of PoTs at several institutions.

Research questions

The distinct nature of the PoT position may be reflected in departmental and institutional networks. The teaching focused nature of the PoT position may result in faculty occupying distinct roles compared to their non-PoT colleagues. The way PoT

positions are distributed within and between departments (e.g. multiple PoTs within single departments and multiple departments with PoTs) may drive network structures that would otherwise not exist in the absence of PoTs.

Here, we examine network data from 17 departments across three separate UC campuses. We focus on the role PoTs play in faculty discussion networks about research, teaching, and in providing advice about teaching. In doing so, we aim to better understand how teaching-focused academic positions as organizational structures may contribute to reforming pedagogy and benefitting higher educational more generally. In doing so, we ask the following research questions (RQs):

1. Do PoTs discuss teaching with and give teaching advice to more colleagues than non-PoTs?

2. Does the presence of PoTs alter teaching and advice discussion network structures within and between departments?

Methods

Data collection

Surveys were administered to faculty in 17 departments across the three university campuses with the greatest number of PoTs. At the time of survey administration, these campuses accounted for over 70% of all PoTs in the UC system (Harlow et al., 2020). Given this study's focus on undergraduate education, the survey was sent to all faculty in these departments assigned to teach undergraduate course(s) in the year the survey was administered. In total, 564 faculty, 34 of whom are PoTs, were sent the survey (Supplemental Table 1).

The survey asked participants to identify other members of their department with whom they have talked about research (research network), about teaching (teaching network), and to identify who is influential on their teaching (advice network). Participants were provided roster lists of other members in their department to select for each interaction type. Additionally, participants were provided the option to write-in other individuals at their university. Questions on the survey were adapted from existing instruments in the K-12 education literature[9] (Daly, 2010) and were previously used at the university level (Apkarian, 2018). Other data about the faculty, including years they have been in the department and whether they serve any administrative roles were also collected.

Some participants listed colleagues who were not sent the survey or were sent the survey but did not complete it. These colleagues were included in the data set, with departmental affiliation and position collected by searching personal and departmental web pages.

Survey responses were compiled into network data structures. Ties were treated as undirected in the research and teaching network based on an assumption that discussions are bi-directional. For example, if Faculty Member A listed Faculty Member B as someone they discuss research with, we treated the tie between A and B were treated as reciprocated, even if B did not list A. in contrast, ties were treated as directed in the advice network based on the assumption that advice is an asymmetric relationship; if A listed B as someone they went to for advice, we treated this as a directed tie from A to B, with a reciprocal tie from B to A only existing if B also listed A as someone they go to for advice.

In some cases, faculty listed postdoctoral scholars, graduate students, and undergraduates as discussion colleagues. Because we were primarily interested in relationships between faculty in more permanent positions, we removed these individuals from the network before analyses.

Analyses for RQ1

To determine whether PoTs communicate with a greater number of colleagues than non-PoTs, we examined degree centrality in the research and teaching network, and in-degree and out-degree centrality in the advice network. Degree centrality is a measure of the total number of ties an individual has in an undirected network, like the research or teaching networks. In-degree and out-degree centrality are measures specific to directed networks and capture the directionality of ties. In the advice network, in-degree centrality equals to the number of colleagues who listed a focal faculty as providing advice about teaching, while out-degree centrality equals to the number of colleagues a focal faculty listed as going to for advice about teaching.

To test whether centrality significantly differed between PoT and non-PoT faculty, we ran network permutation tests with 10,000 permutations. Because lower degree centrality scores are a natural consequence of non-response, we included only the 215 faculty who completed the survey in these analyses. Colleagues who were named in participant responses but who did not complete the survey were included in the network when calculating centrality. Thus, if a faculty member listed four colleagues with whom they discuss teaching, but two of those colleagues did not fill out the survey, that faculty member's degree centrality in that network was treated as four, not two. Further information about the permutation tests can be found in the supplemental materials.

Analysis for RQ2

We used a node-removal procedure to determine whether the presence of PoTs significantly altered the structure of departmental teaching and advice networks compared to the presence of non-PoT faculty. Graph-level centralization was compared in the Teach and Advice networks after removing all PoTs to the centralization after removing an equivalent number of non-PoT faculty. Non-PoT faculty removal was bootstrapped 1,000 times for each department to generate distributions of centralization scores. One-tailed t-tests were used to determine whether perturbations to the centralization score were significantly different when PoTs were removed compared to non-PoTs. These tests were run for the two department networks with the highest response rates (C2D1 and C2D2).

Network centralization can be understood as a measure of inequality in how central different actors are in the network. We use Freeman's (1979) calculation of centralization, which follows the general formula:

$$\sum_{i=1}^{g}[C_D(n^*) - C_D(n_i)]/max\sum_{i=1}^{g}[(C_D(n^*) - C_D(n_i)]$$

Where $C_D(n^*)$ represents the largest observed degree centrality within the network, and $C_D(n_i)$ represents the degree centrality of each of *g* actors in the network (Freeman 1979). Networks have a higher centralization score when the disparity in degree centrality between the most central actor and all other actors is large, and lower centralization when degree centrality is similar among all actors. In-degree and out-degree centralization follow the same formula but replace degree centrality with either in-degree or out-degree centrality.

To better understand the processes and patterns in the Advice network, exponential random graph models (ERGMs) were developed to predict the likelihood that one faculty considers another influential on their teaching. ERGMs are similar to logistic regression, where the dependent variable is the presence or absence of a tie between two nodes. However, unlike logistic regression, ERGMs account for the interdependence inherent to network data. ERGMs can be parameterized with terms at the individual, dyadic, and global level. That is, whether ties are more or less likely based on a characteristic of an actor (individual), a characteristic that exists between two actors, like whether they share similar characteristics (dyadic), or larger structural features of a network, like a tendency for three actors to all be connected to one another (global). Because ERGMs are sensitive to missing data, ERGM models were only fit for the two department networks with the highest response rates (C2D1 and C2D2).

Our modeling approach was exploratory. Individual, dyadic, and global-level variables were sequentially added, with variables kept if they improved model fit (Hunter et al., 2008). The individual-level variables tested included whether or not a faculty is a PoT and the number of years a faculty member has been employed at their institution. The dyadic-level variables tested included whether faculty shared the same PoT status, the absolute difference in how long two faculty had been at their institution, and whether ties were reciprocated. The global-level variables tested included a propensity for faculty to be listed as influential on only one other faculty member, a propensity for faculty to not be listed by any faculty members as influential, and a term for geometrically-weighted edgewise shared partners (GWESP). GWESP models the

likelihood that a tie exists between two faculty, given that these faculty both have ties to one or more of the same other faculty.

To understand the role of PoTs in facilitating interdepartmental discussions about teaching, we first used network permutation tests to test whether 1) the mean number of interdepartmental ties about teaching significantly differed between PoT and non-PoT faculty, and if 2) Krackhardt's E-I indices significantly differed between PoT and non-PoT faculty. E-I Index is a standardized measure of the proportion one's of ties that exist with colleagues within a group compared to ties that exist with colleagues from outside that group (Krackhardt & Stern, 1988). We defined groups as one's academic department. In this instance, a faculty member whose only ties were with colleagues from their home department would have an E-I index of -1, while a faculty member whose only ties were with colleagues from departments other than their home department would have an E-I index of +1. An E-I index of 0 represents a situation where half of one's ties are with colleagues from a home department, and half with colleagues in other departments.

We further examined patterns of interdepartmental ties by fitting ERGMs to subgraphs of the Teach and Advice networks that only included interdepartmental ties. Because our primary interest is understanding the role of PoTs and non-PoTs in these interdepartmental networks, the only variables included in these models were for each possible pairing between PoTs and non-PoTs.

All analyses were performed using the statnet suite of packages in R (Handcock et al., 2008). All data were collected in accordance with the University of California Irvine's Institutional Review Board (Protocol 2015–2499).

Results

Networks overview

Out of 564 total faculty surveyed, 215 faculty consented and completed the survey (38.1%), including 17 out of the 34 PoTs (50%). Response rates varied across departments, with two departments achieving particularly high response rates (86.6% and 91.7%). Response rates from the other ten departments ranged from 19.7% to 63.9% (Supplemental Table 1).

Summary information about the actors and ties in the Research, Teaching, and Advice networks can be found in Table 1. On average, participants had more colleagues with whom they discussed research (mean degree 14.3) than colleagues with whom they discussed teaching (mean degree 9.8) or went to for advice about teaching (mean out-degree 3.29). Participants were listed as someone that was sought out for advice by an average of 1.92 colleagues. Ties were more common between individuals in the same department than across departments, though this propensity varied by network (Table 1). Interdepartmental ties were most common in the Research network (41.8% of research ties), followed by the Teaching network (38.9% of teaching ties) and the Advice network (26.6% of advice ties).

Sociographs of the different networks make these differences between the different networks clear, while also illuminating other structural patterns (Figure 1). Nodes in these networks represent individual faculty. The color of each node indicates the department that faculty belongs to and highlights the tendency for intradepartmental ties over interdepartmental ties. It seems that this tendency may vary by campus, and it

is worth noting that the departments in Campus 3 that appear to show more interdepartmental connections are from similar disciplines and part of the same college.

The size of each node correlates with the total number of connections each individual has; in the Research and Teaching networks, it is based on the degree centrality, while in the Advice network it is based on in-degree degree centrality (how many people go to that individual for advice). PoTs are depicted as triangles, while traditional research faculty are circles. It is evident that faculty vary in the number of connections they have, and PoTs seem to be a bit more pronounced in the Teaching and Advice networks, especially when compared to the Research network.

Many faculty members are tied to otherwise unconnected colleagues. In many cases, these connections are with faculty who did not take the survey, which includes faculty who did not respond and faculty who were not sent the survey, either because they are in a department outside the scope of the study or they did not teach in the year leading up to the study. These connections to otherwise unconnected colleagues appear to be most prevalent in the Research network, where more colleagues were listed in general, and least prevalent in the Advice network.

Do PoTs communicate with more faculty?

Network permutation tests were used to assess whether the average number of ties for PoTs was significantly different from non-PoT faculty. Among the 215 faculty who completed the survey, PoTs had a significantly greater number of discussion partners about teaching and provided advice about teaching to a significantly greater number of colleagues on average than non-PoT faculty. PoT and non-PoT faculty did not significantly differ in the number of colleagues they went to for advice

about teaching, nor did they differ in the number of colleagues with whom they discussed research (Figure 2). These results suggest that, on average, PoTs play a more important role in the dissemination of information about teaching when compared to non-PoT faculty within their institution.

What predicts one faculty going to another for advice about teaching?

We tested which factors predict one faculty seeking teaching advice from another by fitting ERGMs to the C2D1 and C2D2 advice networks. Model results from both departments indicated that PoTs were significantly more likely to be listed as someone who is approached for advice than non-PoT faculty, further indicating the central role of PoTs in providing advice about teaching. This result controls for other potential confounder variables, such as the length of time faculty had been at their institution. PoTs were significantly more likely to be listed as someone that faculty go to for advice about teaching compared to non-PoTs (Supplemental table ERGM, individual models).

ERGMs allowed us to further understand the propensity for PoT and non-PoT faculty to seek advice from faculty in the same position versus faculty in the other position. We found that non-PoT faculty were significantly more likely to go to PoTs for advice than to other non-PoT faculty. Compared to a non-PoT going to another non-PoT for advice, the odds of a non-PoT going to a PoT was 2.64 times greater in C2D1, and 4.35 times greater in C2D2. In C2D2, but not C2D1, PoTs were also significantly more likely to go to PoT for advice about teaching (Table 2, Supplemental table, Supplemental figures).

Another variable that significantly predicted a faculty going to another for advice was how long the faculty had been at their institution. The longer a faculty member had been at their institution, the fewer colleagues they went to for advice about teaching; for each additional year a faculty has been at their institution, the odds of them listing a peer as influential on their teaching drops by 0.03. This effect size was the same in both departments. When considering the likelihood that a faculty member is sought out for advice about teaching by a colleague, the importance of how long the advice-provider had been at their institution was inconsistent between the two departments. In C2D2, the longer a faculty had been at their institution, the more likely they were to be considered influential by a colleague. No evidence of this effect was found in C2D1.

We also examined whether advice ties were predicted by the relative amount of time one faculty had been at their institution compared to another faculty. In C2D2, advice was more likely to be shared between faculty pairs if they had been at their institution for a similar number of years. This type of cohort effect was not found in C2D1, where no effect of relative time at institution between two faculty on an advice tie was found.

Beyond PoT status and length of one's tenure at their institution, several structural properties were prominent in these networks. A positive and significant GWESP term in models for both departments indicates a propensity for edgewise-shared partnerships. This captures a tendency for transitive triads in the network. For example, if both Dr. A and Dr. B listed Dr. C as someone who is influential on their teaching, then this increases the odds that we would observe Dr. A listing Dr. B or Dr. B listing Dr. A. These odds increase for each additional edgewise-shared partnership

between Dr. A and Dr. B. There was a propensity for faculty to either be only listed by one peer or to not be listed at all in C2D1, but not in C2D2. Conversely, there was a propensity for a reciprocal flow of advice between faculty in C2D2, but not C2D1.

Does the presence of PoTs alter departmental structure compared to non-PoT faculty?

We tested whether the presence of PoTs significantly altered the level of centralization in the Teaching and Advice networks compared to non-PoT faculty. Using the C2D1 and C2D2 networks, we compared centralization scores from the full departmental networks, the departmental networks after PoTs were removed, and a distribution of centralization scores generated by iteratively removing a random sample of non-PoT faculty equivalent to the number of PoTs in the C2D1 and C2D2 department, respectively.

Compared to the observed networks and when non-PoT faculty were removed, removing PoTs from the Teaching networks from both C2D1 and C2D2 resulted in a slightly more centralized network structure (Figure 3). This finding is surprising at first glance because, on average, PoTs discuss teaching with more colleagues than non-PoT faculty. The most likely explanation reflects the high centrality of non-PoT faculty in administrative roles in these departments (Supplemental Material).

Conversely, removing PoTs from the Advice networks resulted in a less centralized network structure compared to the observed networks and when an equivalent number of non-PoT faculty are removed (Figure 4). This captures the disproportionate importance of PoTs for providing advice about teaching to colleagues in their department.

What role do PoTs play in facilitating information about teaching between departments?

We examined the role of PoTs in discussions that span between two different departments in several ways. First, we examined the raw number of connections PoT and non-PoT faculty had to colleagues from other departments. Compared to non-PoT faculty, PoTs discussed teaching with significantly more colleagues in other departments (PoT: 7.41, non-PoT: 2.20). PoTs also gave advice about teaching to significantly more colleagues in other departments (PoT: 1.59, non-PoT: 0.20) and received advice from significantly more colleagues in other departments (PoT: 1.88, non-PoT: 0.70) (Figure 5A). No significant difference was found in the number of colleagues from other departments PoT and non-PoT faculty speak to about research.

To understand the relative abundance of colleagues PoTs and non-PoTs have within versus outside of their departments when it comes to discussions about teaching, we tested whether the E-I index differed between PoT and non-PoT faculty. The E-I index differs from the raw number of interdepartmental colleagues by describing the extent to which one's local network is composed of intra- versus inter-departmental colleagues. Across all networks, the mean E-I index was negative for both PoT and non-PoT faculty. This indicates that, on average, both PoTs and non-PoTs had discussions with more colleagues from their own department than from other departments (Table 2; Figure 5B). E-I indices were significantly different between PoT and non-PoT faculty in the Teaching network and in the advice network when considering who they received advice about teaching from. In both cases, PoT's had a greater proportion of colleagues from other departments compared to non-PoTs. This

suggests that colleagues from other departments might have more relative influence on PoT teaching compared to non-PoTs, on average. The mean E-I index was not significantly different between PoTs and non-PoTs in the research network and regarding who they gave advice to.

We further explored the role of PoTs and non-PoTs in bridging ties between departments by using ERGMs to model subgraphs including only interdepartmental ties (Supplemental Table). This allowed us to compare the odds of an interdepartmental tie existing between two PoTs, two non-PoTs, or between a PoT and a non-PoT. The log-odds that interdepartmental discussions about teaching occur between two faculty were significantly higher if one of these faculty was a PoT (Figure 5A). Relative to the odds of an interdepartmental tie between two non-PoT faculty from, the odds of an interdepartmental tie between two PoTs or between a PoT and a non-Pot were 27.9 times and 2.7 times greater, respectively.

A similar pattern was found in the advice network (Figure 6B). Relative to the odds of a non-PoT faculty going to a non-PoT faculty from a different department for teaching advice, the odds of a non-PoT going to a PoT was 4.65 times greater. The odds of a PoT going to another PoT was 25.07 times greater than a PoT going to a non-PoT colleague, while the the odds of a PoT going to another PoT was 27.66 times greater than the odds of a non-PoT going to a non-PoT. Despite representing a small proportion of faculty at their institutions, it is clear that PoTs are heavily engaged in disseminating information about teaching across departments.

Discussion

In our examination of faculty discussion networks from 19 departments across three university campuses, we found that PoTs play a role distinct from their colleagues in traditional research-focused positions when it comes to discussions about teaching. PoTs discussed and provided advice about teaching to significantly more colleagues than research-focused faculty. This pattern is largely explained by non-PoT faculty disproportionately going to PoTs for teaching advice. The implications of PoTs discussing teaching with many departmental colleagues was seen in network structures at the larger group level, suggesting that PoTs' roles in their departments expand beyond individual or dyadic levels. We also found that PoTs are the primary bridges for discussions about teaching between departments, and thus provide a main avenue for information about teaching to spread at an institutional level. In contrast, PoTs and non-PoTs have similar levels of connectivity when it comes to discussions about research. On average, PoTs and non-PoTs did not differ in the number of peers they discussed research with, either inside or outside of their own department. This is somewhat surprising; while PoTs have research expectations, their distribution of effort places an emphasis on teaching over research (Harlow 2020). Overall, these data suggest that PoTs are integrated within their campuses' interpersonal networks.

We were primarily interested in the role of PoTs in these networks in order to evaluate their potential for promoting pedagogical reform within their institutions. While both PoTs and research-focused faculty contribute to the undergraduate education mission of STEM departments, administrators identify PoTs as bringing novel viewpoints and expertise (Harlow, in preparation). This is reflected in the designated roles, responsibilities, and incentives that distinguish PoTs from other faculty. Here, we

have shown that the emergent relational networks of faculty in these positions are also distinguished from other faculty. This is promising from the perspective of driving organizational change.

Situated to enact departmental change

PoTs may be facilitating pedagogical change in the beliefs and behaviors of their colleagues. The most direct evidence of this is their central role in departmental discussions about teaching, including disseminating advice. The similar roles across both of these networks indicates that PoTs' expertise is being recognized and accessed by their colleagues. These results differ slightly from those found in faculty discussion networks in departments with DBER scholars; DBER scholars and traditional research-focused faculty did not significantly differ in the total number of intradepartmental colleagues they spoke to about teaching, though did differ in the number of colleagues' teaching influenced by these discussions (Andrews et al., 2016).

Direct impacts PoTs may be having on their peers expands when one considers their overall centralizing effect on departmental advice networks. This increased graph-level centralization elevates the potential for change created by PoTs, as beneficial behaviors of the most central actors are expected to disseminate particularly rapidly when networks are highly centralized (Liu et al., 2005; Valente, 1996). This effect may be compounded by the observed tendency for edgewise-shared partners in the advice networks. This type of clustering can promote diffusion of innovation, so long as adopters of this information are within these clusters (Acemoglu et al., 2011), which appears to be the case with PoTs.

Interestingly, PoTs did not have the same centralizing impact on the teaching networks as they did in advice networks. This was a result of several non-PoT faculty with administrative roles occupying highly central positions within their departments' network. The different results between these two networks suggests that PoTs have a pronounced role in discussions about teaching, where they tend to influence the instruction of their colleagues as opposed to simply discussing logistics about teaching. This finding aligns with previous results with DBERs, who did not differ from traditional research faculty in the number of peers they discussed teaching but were more likely to be listed by colleagues as influencing teaching practice (Andrews et al). These results are also supported by interviews with administrators, who perceived PoTs as having a distinct role compared to research-focused faculty, e.g. having exceptional teaching abilities and education research expertise, securing external education-focused grants, and leading curriculum accreditation efforts (Harlow et al., 2021). Therefore, PoTs are structurally situated to enact departmental change in a way that may not be possible with research-focused faculty.

Information brokers across departments

While the siloed nature of disciplinary research is well-known (Frodeman et al., 2017; McLevey et al., 2018), less is known about disciplinary silos when it comes to communication about pedagogy. Our results make it clear that discussions about teaching between faculty in different departments are rare compared to discussions about research, especially for traditional research-focused faculty. However, this does not mean that interdepartmental communications about teaching were absent. PoTs were prominent in brokering pedagogical information across departments compared to

research-focused faculty. To match the level of engagement the 17 PoTs who completed the survey had in providing advice to colleagues in other departments, it would take 140 research-focused faculty, an eight-fold difference.

Given the extraordinary difference in interdepartmental communication, it is worth considering why PoTs may find themselves in this brokerage role, and what the implications of these informal interdepartmental channels may be. Perhaps the simplest explanation for this disparity is that it is a reflection of the greater engagement in discussions about teaching shown by PoTs. However, while PoTs did provide advice to a significantly greater number of intradepartmental colleagues, this disparity was much lower than that found for interdepartmental communications. An additional consideration is that PoTs are better at discussing teaching with faculty from other disciplines than non-PoTs. The ability to communicate across expertise is recognized as an important prerequisite skill for one to successfully serve as an information broker (Meyer, 2010). If PoTs have a deeper, more conceptual understanding and approach to pedagogy, this would likely enable more productive discussions about pedagogy with colleagues in other departments, and likely more frequent discussions. This may contrast with other faculty whose discussions may place more emphasis on disciplinary-specific issues in their courses.

Another possibility is that PoTs desire discussing pedagogy with like-minded colleagues and must expand beyond their own department to find these individuals. Prior research suggests that faculty with greater pedagogical knowledge preferentially discuss teaching with colleagues with similar levels of knowledge (Lane et al., 2020). This aligns with the finding that PoTs had a strong propensity to interact with other PoTs

in other departments. However, more information about the nature of the non-PoT faculty who had ties to PoTs is needed to fully evaluate whether this is the case.

Regardless of the reason, PoTs may benefit their institutions by brokering pedagogical information between departments. First, they may transmit novel and useful information to each department they bridge. Useful innovations that originate in one department will be more likely to show up in another if informal communication channels exist. Second, this network position may help PoTs themselves become more innovative. That is, exposure to diverse ideas from different disciplinary cultures may aid the creation of new knowledge.

Both of these potential benefits to the institution relate to the concept of structural holes (Burt, 2004, 2009). As conceptualized, the idea behind structural holes is that individuals face both advantages and disadvantages by playing the role of a broker. Parallel to the potential institutional benefits discussed above, PoTs themselves may be rewarded for their ability to transmit novel information to their department or innovate new pedagogical strategies. However, in an academic environment that often rewards siloed behaviors, expending too much energy on communications outside of one's own department may be costly.

Importance of local and global context

Beyond understanding the network roles of PoTs, this study also illuminates the importance of local and global contexts to faculty networks. While variables predictive of ties in two departments' networks were similar, they were not identical, even though these departments were in the same school on the same campus. This suggests that

social processes that occur in one department are not perfectly generalizable to other departments, an essential consideration for work moving forward and similar initiatives taking place in other universities. Instead, it is important to consider academic departments as their own communities of practice (Jawitz, 2009) or organizational units (Reinholz & Apkarian, 2018), complete with their own behavioral norms and expectations. The nature of academic departments as silos may give rise to unique local contexts that support departmental structural and cultural differences, even when two departments have substantial commonalities. Therefore, our results call for future work to contextualize departmental structures and cultures more deeply and integrate this with an understanding of how they may permit or constrain the ability of PoTs and faculty in similar positions to promote pedagogical change. While some of our results corroborate with those found among DBERs in the US context (Andrews et al., 2016), whether these findings are generalizable to teaching-focused academic positions in non-US contexts is unclear. Potential structural and cultural differences among higher education systems create uncertainty in whether the roles of faculty in teaching-focused positions outside of the US would reflect those of PoTs.

Limitations:

In this study, we were able to describe the structures and patterns of faculty discussion networks. While the position of PoTs within these networks suggests that they are particularly influential on their colleagues' instruction, we are unable to discern whether any behavior change is actually taking place, as we did not collect any pedagogical data on these faculty. The extent to which pedagogical behaviors change as a result of one’s interpersonal ties remains unclear. Elucidating these types of social

influences in network studies is notoriously difficult, and typically requires longitudinal data.

The survey used to collect these data did not include information about the intensity or frequency of interactions between actors. Thus, all ties were treated equivalently, even though some were likely stronger than others. However, additional information about tie strength would allow a deeper understanding of these networks. This includes testing whether the high connectivity of PoTs in teaching discussions came at the cost of interaction frequency versus a situation where PoTs not only had the greatest number of colleagues in teaching networks, but also the strongest ties. Lastly, while PoTs are considered influential by many colleagues, the current data do not allow us to distinguish the ways in which they are influential. Important next steps would be to clarify the ways in which PoTs influence their colleagues' pedagogy.

Conclusion

Given the uniqueness of the PoT position among the myriad of teaching-focused academic positions and the administrative intentions for PoTs to help drive pedagogical reform, we sought to understand the role they play in their departmental and institutional networks. Our results provide support to the strategy of embedding PoTs across different disciplinary departments. PoTs are not only highly central in their own departmental discussion networks about teaching, but also bridge information across departmental boundaries. Faculty in these positions appear to be the most important relational resource for teaching within their departments, while the pervasiveness of PoTs across departments leads to their ability to restructure the overall institutional network. While the network positions of PoTs suggest this potential for reform, further

research should examine the types of impacts PoTs have on the pedagogy of their colleagues.

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Figure 1: Sociographs of the three different networks across all three different campuses. Each node represents a faculty member. Node color corresponding to distinct departments. While colors are re-used between the different campuses to represent distinct departments, nodes colored yellow represent faculty from departments that were not surveyed for all three campuses. Node shape corresponds to whether a faculty is a PoT (triangle) or not (circle). The size of each node correlates with degree centrality in the Research and Teaching networks, and with indegree centrality in the Advice network.

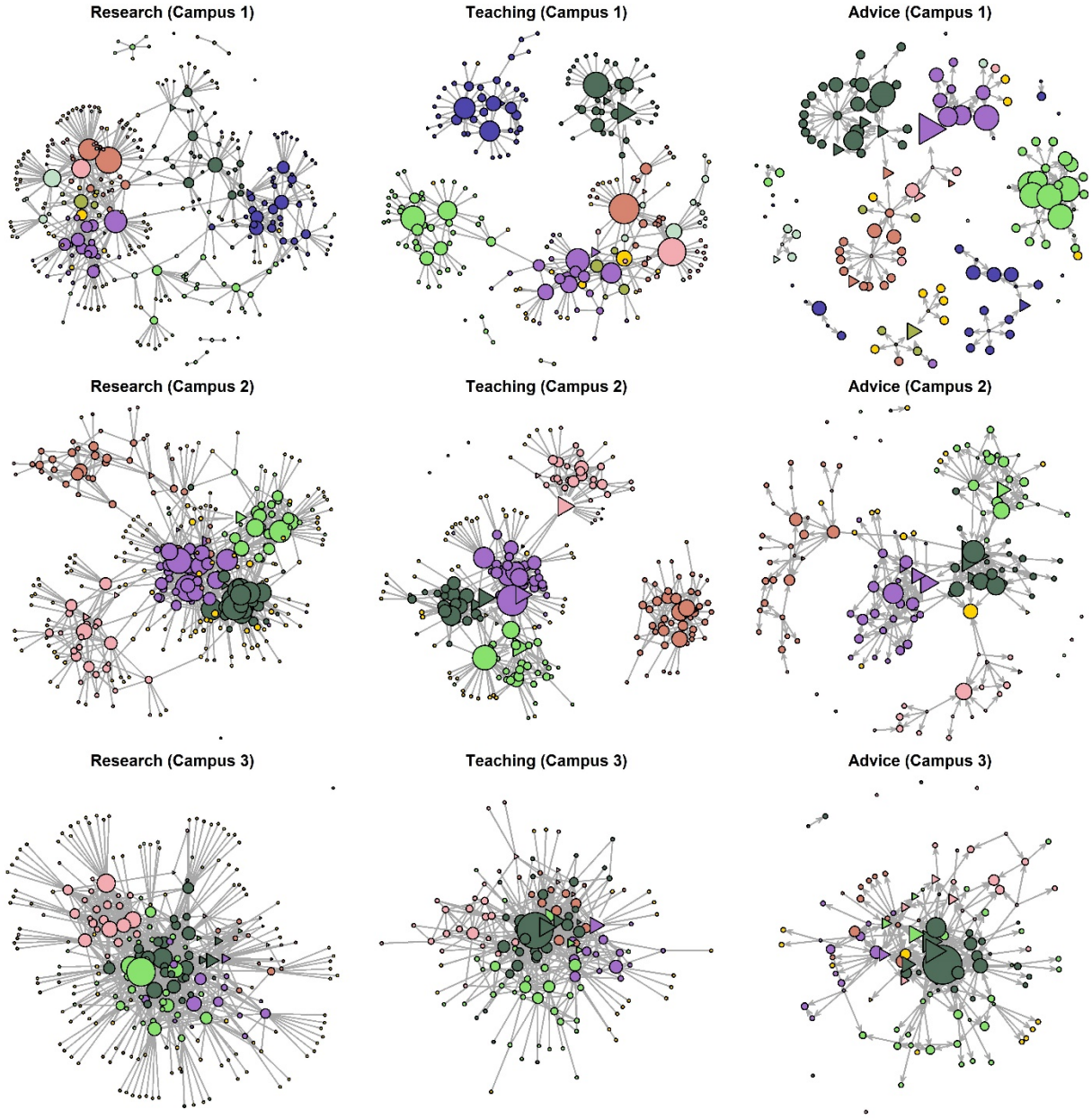

Figure 2: Mean degree centralities and standard errors for PoT and non-PoT faculty across the different networks among the 215 faculty respondents.

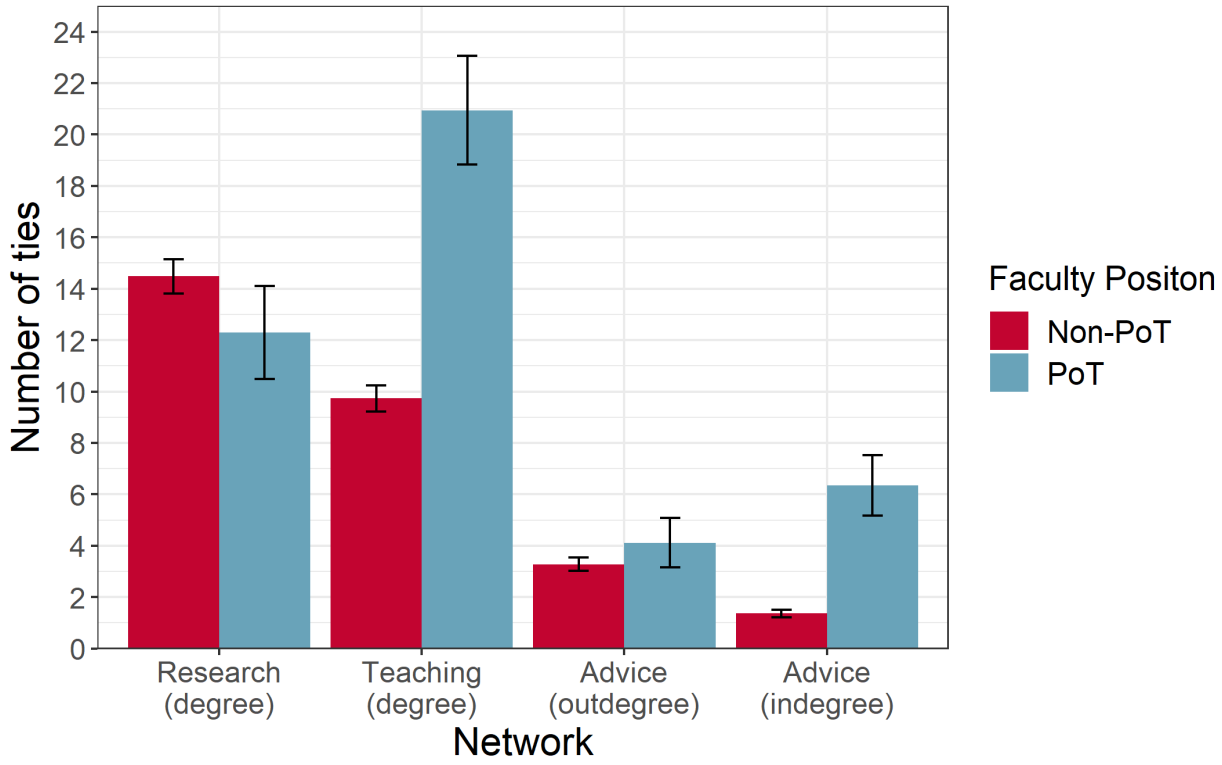

Figure 3: Graph level centralization of the C2D1 and C2D2 Teaching networks compared to the centralization when the PoT faculty are removed and when an equivalent number of non-PoT faculty are removed. No variation exists in the No Deletion and PoT Removed scenarios because, in both cases, only one network structure is possible.

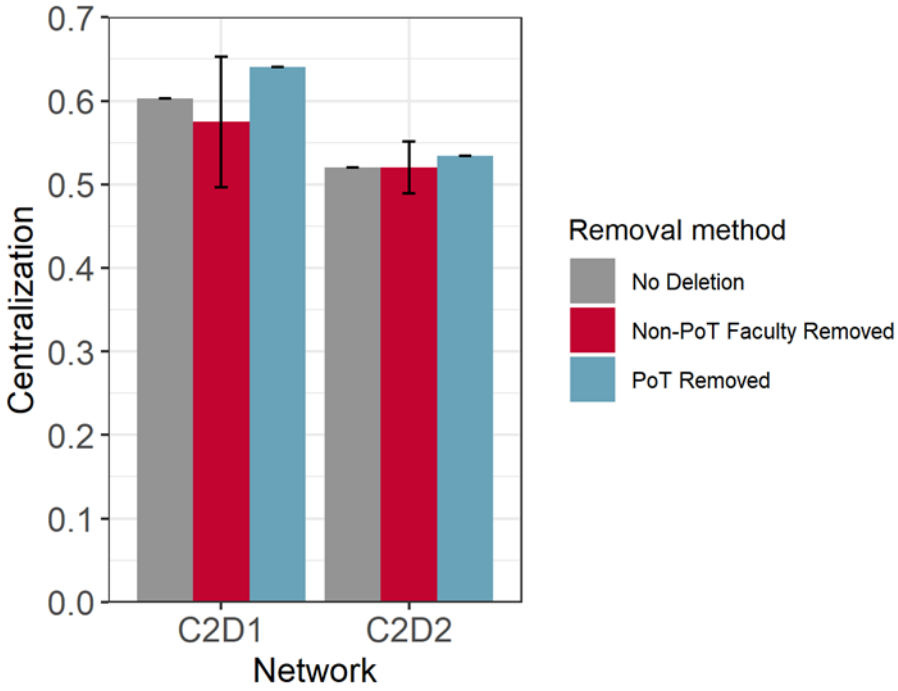

Figure 4: Graph level centralization of the C2D1 and C2D2 Advice networks compared to the centralization when the PoT faculty are removed and when an equivalent number of non-PoT faculty are removed. No variation exists in the No Deletion and PoT Removed scenarios because, in both cases, only one network structure is possible

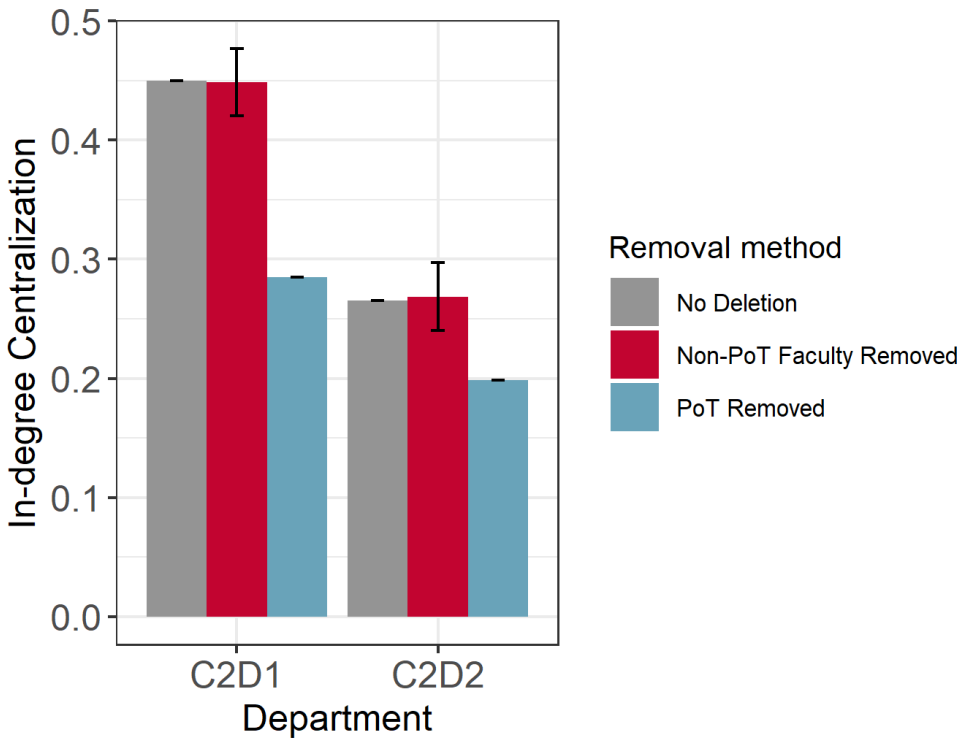

Figure 5: A) Total number of interdepartmental ties in each network for PoT and non-PoT faculty. B) E-I index in each network for PoT and non-PoT faculty. An E-I index of 1 indicates all ties connecting to colleagues in other departments, while an E-I index of -1 indicates all ties connecting to colleagues from within one's own department.

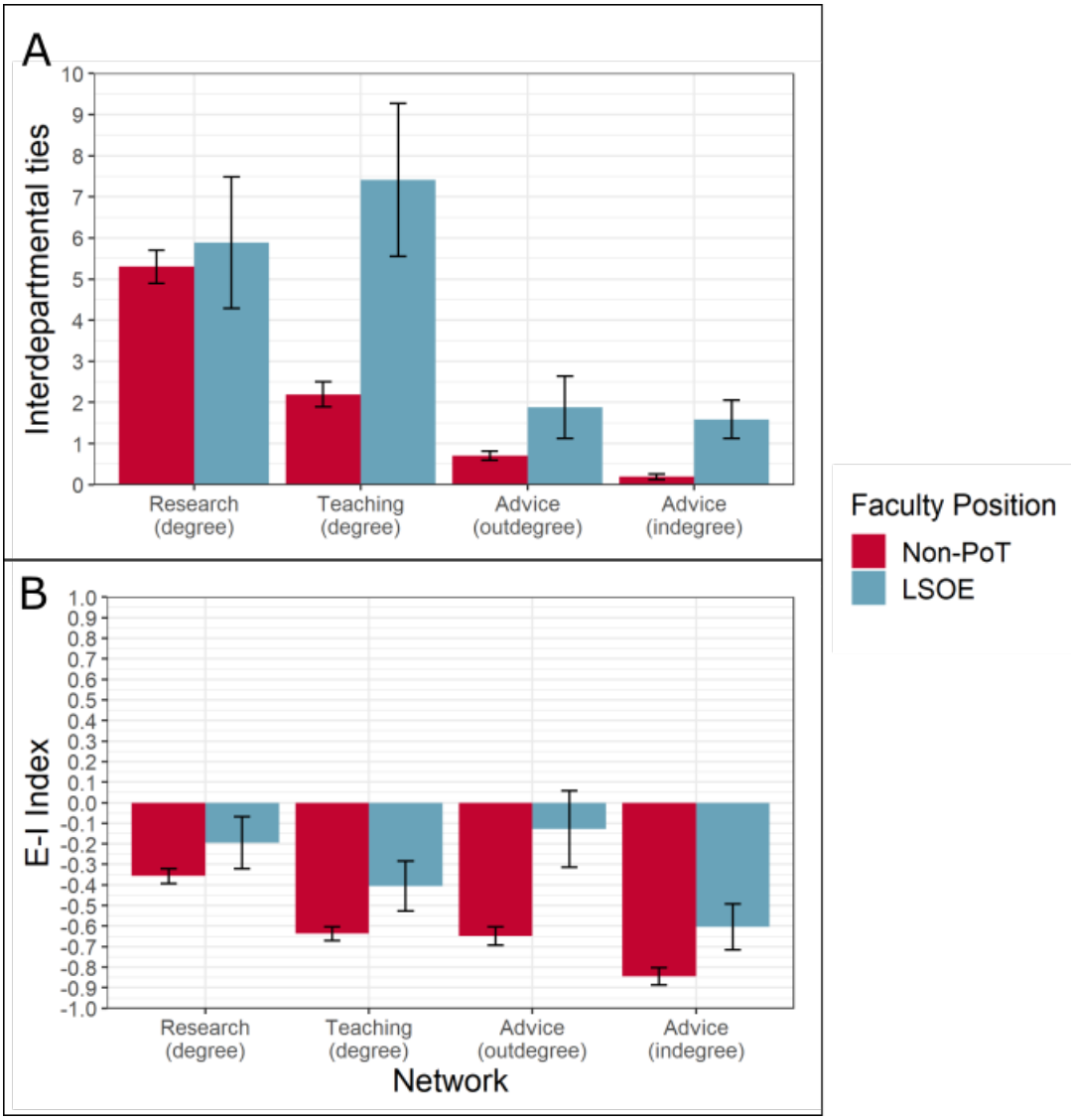

Figure 6: Log-odds of ties estimated by ERGM models of sub-graphs representing only interdepartmental ties in the Teaching network (A) and the Advice network (B). Two Non-PoT faculty are used as the reference level in models for both networks. Coefficients thus represent the change in the log-odds of a tie if two faculty are of the corresponding PoT/Non-PoT combination as opposed to both being Non-PoTs.

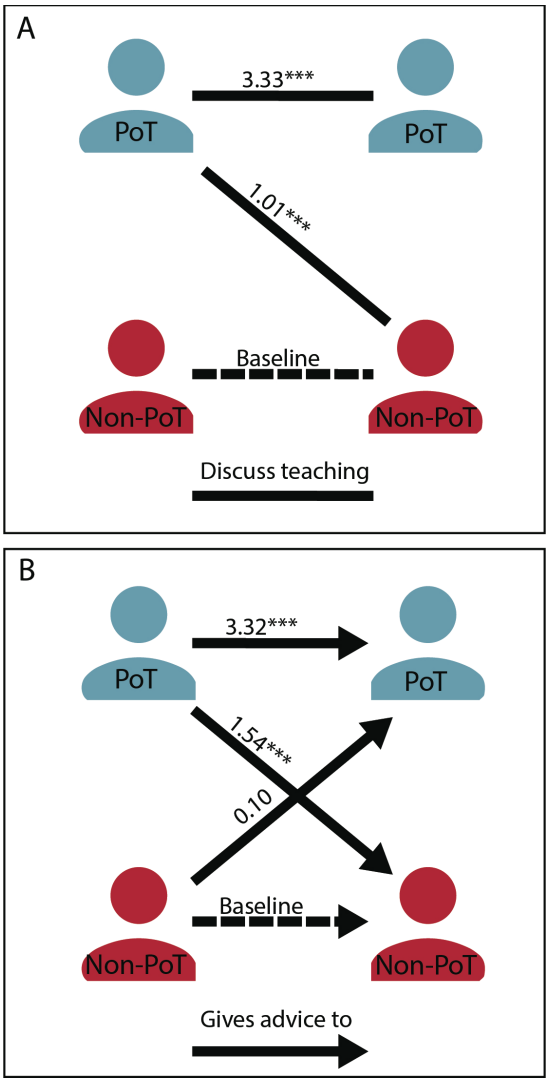

Table 1: Summary information for the Research, Teaching, and Advice networks.

	Research	**Teaching**	**Advice**
Individuals in network (includes undergrads, grad students, and post-docs)	967	595	403
Faculty and staff in network (no undergrads, grad students, or postdocs)	892 (92.2%)	590 (99.2%)	403 (100%)
Faculty and staff from surveyed departments	560 (62.8%)	498 (84.4%)	374 (92.8%)
Faculty and staff from non-surveyed department	332 (37.2%)	92 (15.6%)	29 (7.20%)
Total ties between all faculty and staff	2323	1572	724
Number of intradepartmental ties	1352 (58.2%)	1154 (73.4%)	553 (76.4%)
Number of interdepartmental ties	971 (41.8%)	850 (38.9%)	171 (23.6%)
Mean degree of 215 participants (sd in parentheses)	14.31 (9.29)	10.61 (7.85)	*Indegree:* 1.75 (2.82) *Outdegree:* 3.35 (3.64)
Isolates (out of 215 participants)	5	4	*Indegree:* 88 *Outdegree:* 46

Table 2: ERGM results of best fitting models for Advice networks in C2D1 and C2D2.

		C2D1			C2D2		
		Est	**Std**	**p-value**	**Est**	**Std**	**p-value**
	Edges	-1.12	0.43	0.009	-1.91	0.34	< 0.001
Individual-level Terms							
	PoT - out-degree (Reference: Non-PoT)	-1.92	0.82	0.019	-3.53	0.83	< 0.001
	Years at institution (in-degree)	-	-	-	0.04	0.01	< 0.001
	Years at institution (out-degree)	-0.03	0.01	0.034	-0.03	0.01	0.003
Dyadic-level Terms							
	Mutual	-	-	-	0.98	0.45	0.030
	Both faculty PoTs (Reference: Non-PoT -> PoT)	1.71	1.70	0.313	3.99	0.90	< 0.001
	Both faculty Non-PoTs (Reference: Non-PoT -> PoT)	-0.97	0.34	0.005	-1.47	0.34	< 0.001
	Difference in years at institution	-	-	-	-0.02	0.01	0.058
Global-level Terms							
	Indegree (0)	1.85	1.23	0.134	-	-	-
	Indegree (1)	1.98	0.86	0.022		-	-
	GWESP	0.67	0.21	0.001	0.91	0.13	< 0.001