



# Innovative teaching knowledge stays with users

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**Programs seeking to transform undergraduate science, technology, engineering, and mathematics courses often strive for participating faculty to share their knowledge of innovative teaching practices with other faculty in their home departments. Here, we provide interview, survey, and social network analyses revealing that faculty who use innovative teaching practices preferentially talk to each other, suggesting that greater steps are needed for information about innovative practices to reach faculty more broadly.**

evidence-based instructional practices | institutional change | social network analysis | STEM education | undergraduate

At its best, effective teaching involves collecting evidence of outcomes from various teaching strategies and using that evidence to guide instructional decisions. This process of using evidence to direct teaching choices represents a defining feature of a learner-centered instructional approach. Evidence-based instructional practices (EBIPs) are codified strategies that align with this goal. Given their demonstrated potential for improving student outcomes, particularly for students from underserved groups, the adoption of EBIPs has critical implications for creating equitable college environments and cultivating a diverse science, technology, engineering, and mathematics (STEM) workforce (1). Despite numerous local and national initiatives to promote instructional change, EBIPs remain underutilized in college STEM courses (2).

Traditionally, many change initiatives have hosted workshops, symposia, or faculty learning communities to promote EBIP adoption by interested faculty (3). Some of these initiatives have also aimed for a secondary impact in which program participants communicate their new knowledge to colleagues, leading to broader EBIP use across departments and institutions (4, 5). According to the theory of diffusion of innovations, this secondary diffusion represents an essential mechanism facilitating the spread of new ideas or technologies through a group or society (6). Specifically, so-called early adopters must communicate with others who have less knowledge or experience for an innovation to become widespread. Adapted to postsecondary education settings, faculty with greater EBIP expertise must talk to less knowledgeable peers for EBIPs to diffuse throughout a department or institution.

Social network analyses in science departments reveal a connection between a person's teaching discussion partners and their EBIP use (7). However, it remains unclear who regular EBIP users talk to about teaching and if they speak to colleagues with less EBIP experience, as necessary for diffusion to occur. A recent study from one biology department found that instructors with high self-reported use of one EBIP (i.e., formative assessment) most often spoke to each other rather than with instructors who had less experience with that EBIP (8). These results suggest that ordinary faculty interactions may not support broader EBIP dissemination, but we do not know whether this finding applies to

innovative teaching practices more broadly as well as within different disciplinary contexts. Knowing to whom EBIP users speak, why they speak to certain colleagues, and whether conversations occur between faculty who use different instructional approaches will provide critical insights into whether secondary diffusion represents a viable change strategy.

## Methods and Results

We conducted a mixed-methods, multi-institutional study to characterize to whom EBIP users talk about teaching. Participants came from nine departments representing three science disciplines at three research-intensive universities in the United States. This research was approved by the Institutional Review Boards at all three institutions (Boise State University, University of Nebraska–Lincoln, and University of South Florida), and participants gave informed consent. Importantly, these institutions had implemented institutional change initiatives, providing various opportunities for faculty to gain EBIP knowledge. We administered a social network survey ( $n = 192$  faculty participants) across these nine departments. All nine departments reached 50% participation and five of the nine departments analyzed had over a 70% response rate (9). On the survey, faculty were asked to respond to a question designed using Guttman scaling where they indicated their knowledge and use of EBIPs (10). We also conducted semistructured interviews with 19 faculty who self-reported on the survey as regularly using EBIPs in their classes (i.e., "high EBIP users"). We used qualitative content analysis to understand why high EBIP users talk to other faculty about teaching.

Qualitative analysis revealed that about half of the high EBIP users interviewed reported speaking about teaching with certain colleagues because they share the same teaching values, such as teaching philosophies and use of innovative teaching practices (Fig. 1). This result was summarized by one interviewee who said, "Over time, I've learned that they [colleagues] have similar views as I do, that they value teaching, and they see their role kind of as that facilitator of learning and a partnership in the classroom with your students.... I feel like we have a similar teaching philosophy." High EBIP users also reported talking to people who have teaching expertise or experiences that the interviewees valued.

From the interview results, we hypothesized that high EBIP users speak to other high EBIP users more frequently than to faculty with little to no EBIP use (i.e., "low EBIP users"). We tested this hypothesis using social network data acquired through the surveys that asked faculty to report which departmental colleagues they discussed teaching with during the last year. We

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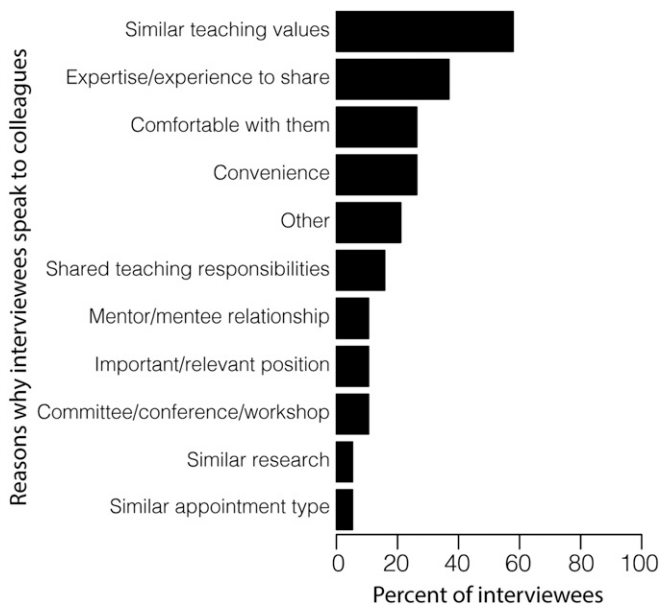
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**Fig. 1.** Reasons for talking to people about teaching. The percent of participants who were coded as having each reason for talking to people about teaching. Participants can be included in more than one category.

used exponential random graph models (ERGMs, ref. 11), a common social network modeling method, to estimate the likelihood of ties between pairs of faculty with certain attribute scores (e.g., EBIP use). Despite various response rates across departments, the EBIP use variable had sufficient variation among respondents to be tested.

ERGM model results support the hypothesis that faculty who regularly use EBIPs preferentially discuss teaching with other high EBIP users (Fig. 2). Specifically, the probability of a high EBIP user discussing teaching with another high EBIP user is greater than the comparable probability for any other combination (i.e., high with low, low with high, or low with low). Low EBIP users are least likely to be cited as discussion partners by both high and low EBIP users. Combining statistical and qualitative analyses provides evidence that high EBIP users are more likely to talk to each other because they have shared teaching approaches and can learn from each other's experiences. Low EBIP users are less likely to be engaged in conversations about innovative teaching approaches as they are less likely to be sought out by or reach out to high EBIP users. The lack of conversations suggests that EBIP knowledge is unlikely to reach low EBIP users through a secondary diffusion process.

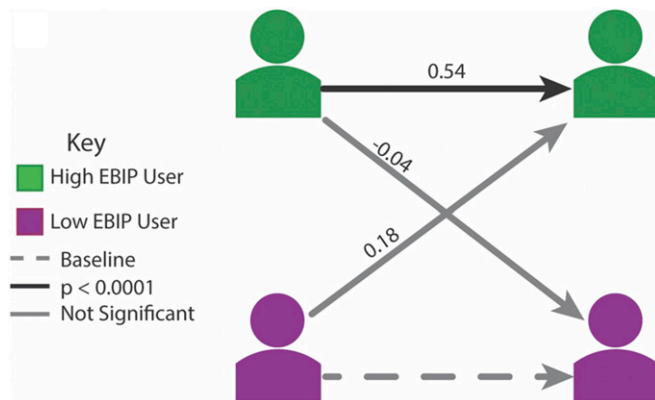
### Discussion

This study suggests that knowledge about innovative teaching is predominantly shared among faculty with teaching approaches that align with these innovative approaches (i.e., EBIP users primarily speak to other EBIP users). Furthermore, faculty identified shared teaching values, experiences, and responsibilities as some of the reasons for why they select specific colleagues with whom to engage in teaching discussions. Thus, interventions seeking to shift teaching practices need to provide incentives and support to engage the full range of faculty in teaching conversations, so that institutions and departments can develop a collective view of teaching that aligns with evidence-based practices. Incentives should be aimed at encouraging high and low EBIP users to seek out interactions that enable them to develop their teaching practices. Fostering these faculty interactions will require a systems approach to altering educational structures, environments, and policies. Below, we describe steps that departments and institutions can take to encourage conversations between faculty with different teaching approaches and ultimately spur the spread of EBIP information and practice.

**Coteaching and Teaching Teams.** Departments and institutions can leverage shared experiences between instructors to encourage teaching conversations. One method may be to create teaching assignments that encourage interaction between faculty with different teaching practices (12). These assignments could go so far as to include formal coteaching where two faculty teach the same course section. A similar outcome may be achieved by creating teaching teams where faculty with different approaches teach different sections of the same course but are also expected to work together to develop course objectives, instructional strategies, and student assignments. This collaboration can encourage the development of shared vision, resources, and expectations around teaching, thereby breaking down barriers to instructional growth.

**Leadership Development.** Departmental and institutional leaders play pivotal roles in successfully implementing new practices in part because they determine institutional commitments and resource allocation (13). Campus leaders also make important decisions regarding personnel, committees, and broader initiatives that shape faculty priorities and interactions. For instance, faculty may not adopt EBIPs if campus leadership does not sufficiently reward excellence in teaching. Policies and calls for reform have repeatedly stressed the need to rework promotion, tenure, and student evaluation systems to support teaching innovation. Therefore, beyond caring deeply about teaching, campus leaders should be knowledgeable about how hiring, promotion, and evaluation practices can support EBIP adoption. Further, understanding how these dynamics play out at teaching-focused institutions remains an important area for future work. Some institutions have created leadership development initiatives to train current or prospective campus leaders. These programs often focus on understanding and implementing the institutional mission (14). This training could include specifics on promoting EBIPs by cultivating environments in which faculty share teaching knowledge and expect EBIP use from colleagues. Leadership development programs could leverage existing resources such as on-campus workshops, teaching and learning centers, and national programs such as the PULSE network (5) to provide some of this training.

**Change Theories.** Ultimately, knowing how best to implement change requires research into mechanisms that challenge the status quo. Our study highlights faculty teaching interactions as



**Fig. 2.** Impact on log odds of a teaching discussion tie being present. Arrows indicate likelihood of EBIP users reporting that they speak to high or low users about teaching. Numbers above the arrows are the modeled rate of nominations between users with reported conversations between low users (dashed arrow) serving as the baseline. The low-to-low baseline has the assigned value 0.00 and the others are calibrated relative to this value. This analysis controlled for the overall tendency to send ties based on reciprocity and on being at the same university and in the same discipline.

an important component in understanding institutional change in higher education. We propose that change theories used to guide teaching reform initiatives should include a component related to faculty interaction (15). Theories of change can also carefully consider how faculty discuss teaching at a given institution and how that can be leveraged or further promoted by the change initiative.

The approaches we describe here challenge current higher education norms and deserve greater attention given the vocal support for student equity expressed by the higher education community. As our data show, even at institutions with available EBIP knowledge and support for instructional change, faculty who use EBIPs are not routinely discussing teaching with their peers who do not use EBIPs. Since faculty are not sharing their knowledge, change initiatives that rely on nonincentivized diffusion can be expected to have limited impact (reaching only a

relatively small number of faculty who are intrigued by instructional change). Instead, we must consider broader changes throughout the higher education system to ensure that we are providing the most effective teaching possible for our students.

**Data Availability.** Anonymized survey data and R code relevant to these analyses are in [Datasets S1–S3](#). Interview transcripts cannot be made available to protect the confidentiality of interviewees, but portions can be provided upon request and after review by the corresponding authors.

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1. E. J. Theobald *et al.*, Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math. *Proc. Natl. Acad. Sci. U.S.A.* **117**, 6476–6483 (2020).
2. M. Stains *et al.*, Anatomy of STEM teaching in North American universities. *Science* **359**, 1468–1470 (2018).
3. C. Henderson, A. Beach, N. Finkelstein, Facilitating change in undergraduate STEM instructional practices: An analytic review of the literature. *J. Res. Sci. Teach.* **48**, 952–984 (2011).
4. C. Pfund *et al.*, Professional development. Summer institute to improve university science teaching. *Science* **324**, 470–471 (2009).
5. S. Musante, PULSE: Implementing change within and among life science departments. *Bioscience* **63**, 254 (2013).
6. E. M. Rogers, *Diffusion of Innovations*, (Free Press, New York, 2003).
7. A. K. Lane *et al.*, Investigating how faculty social networks and peer influence relate to knowledge and use of evidence-based teaching practices. *Int. J. STEM Educ.* **6**, 28 (2019).
8. M. McConnell, L. Montplaisir, E. Offerdahl, Meeting the conditions for diffusion of teaching innovations in a university STEM department. *J. STEM Educ. Res.* **2019**, 1–26 (2019).
9. S. P. Borgatti, K. M. Carley, D. Krackhardt, On the robustness of centrality measures under conditions of imperfect data. *Soc. Netw.* **28**, 124–136 (2006).
10. R. E. Landrum, K. Viskupic, S. E. Shadle, D. Bullock, Assessing the STEM landscape: The current instructional climate survey and the evidence-based instructional practices adoption scale. *Int. J. STEM Educ.* **4**, 25 (2017).
11. S. Wasserman, G. Robins, “An introduction to random graphs, dependence graphs, and p” in *Models and Methods in Social Network Analysis*, P. J. Carrington, J. Scott, S. Wasserman, Eds. (Cambridge University Press, 2005), pp. 148–161.
12. C. Henderson, A. Beach, M. Famiano, Promoting instructional change via co-teaching. *Am. J. Phys.* **77**, 274–283 (2009).
13. A. E. Austin, Promoting evidence-based change in undergraduate science education. [https://sites.nationalacademies.org/cs/groups/dbassesite/documents/webpage/dbasse\\_072578.pdf](https://sites.nationalacademies.org/cs/groups/dbassesite/documents/webpage/dbasse_072578.pdf). Accessed 4 May 2020.
14. A. E. Austin, M. D. Sorcinelli, The future of faculty development: Where are we going? *New Dir. Teach. Learn.* **2013**, 85–97 (2013).
15. D. L. Reinholz, T. C. Andrews, Change theory and theory of change: What’s the difference anyway? *Int. J. STEM Educ.* **7**, 1–12 (2020).