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Practices for Implementing Interactive Teaching Development Groups

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ABSTRACT

This paper reports on a two-year project to form teaching development groups in engineering departments. The goal of each group was to discuss and implement interactive teaching strategies (e.g., in-class problem solving). The research design used meetings notes, feedback from group leaders and a case study of one participant to describe how the groups can be designed to support teaching development. This research was grounded in the following questions: What are the design principles underlying a successful, ongoing, small-group model for faculty teaching development? What logistical and structural features are important for ongoing faculty teaching development in a small-group format? This paper presents the five principles identified in the study and provides a case study of an engineering faculty member's teaching innovations over the several years during and after his participation in the faculty development group.

Key words: faculty development, interactive teaching, learning communities

INTRODUCTION

> "Student engagement, we argue, begins with faculty engagement." (Chen, Lattuca, and Hamilton 2008, 341)

Chen, Lattuca and Hamilton examined and described how students' engagement in their learning is influenced by faculty members' engagement in improving their teaching and increasing student involvement during class (2008). They attributed students' increased abilities to solve open-ended problems and practice good design to increased engagement with engineering content. Hence, faculty engagement in teaching begins with their own professional development to learn about strategies conducive to student engagement. The goal of our work with engineering faculty was to encourage the development and implementation of interactive teaching and formative assessment strategies that are consistent with models for how people learn. Much research has concluded that interactive teaching that includes regular formative assessment — moving beyond traditional lecture models — is more effective for students' learning and engagement with engineering (Prince 2004; Smith et al. 2005; Freeman et al. 2014). However, bridging the gap to implementation beyond laboratories and similar settings remains a challenge (Jamieson and Lohmann 2012). Surveys of engineering departments have found that though there may be knowledge of research-based teaching practices, there is still reluctance to use them (Henderson and Dancy 2011).

We propose, analyze, and elaborate on guiding principles for one possible model to address this challenge. The model design focuses on small teaching development groups in which faculty to discuss teaching practice and explore new teaching strategies. This model created and supported small groups of engineering and other faculty over a two-year period to use interactive, formative teaching strategies in their classrooms. The study employed a design research theoretical framework to shape the research and implementation. The researchers (first two authors of this paper) conducted a qualitative analysis of data collected during the two-year project. Our participants included tenured, tenure-track and term (teaching only non-tenure-line) faculty members, as well as graduate students; we refer to them collectively as "instructors" throughout this paper since they are all focused on teaching and learning in this context. This project was grounded in the following questions: What are the design principles underlying a successful, ongoing, small-group model for faculty teaching development? What logistical and structural features are important for ongoing faculty teaching development in a small-group format? This paper presents the five principles identified in the study and provides a case study of an engineering faculty member's teaching innovations over the several years during and after his participation in the faculty development group. The innovation was in identifying a department-based model for faculty development that supported faculty adoption of new teaching practices.

BACKGROUND LITERATURE

Several previous studies investigated faculty development of interactive teaching practices (Cox and Harris 2010; Light et al. 2008; McKenna, Yalvac, and Light 2009). As reported in Jamieson and Lohman

(2012), some faculty development efforts have been successful (particularly with junior faculty) (e.g., Cox and Harris 2010; Light et al. 2008), but there are still significant numbers of faculty using traditional pedagogical methods. One problem is the limited time faculty may have available to devote to developing their teaching and the lack of knowledge faculty may have about interactive teaching strategies (Henderson and Dancy 2011). Earlier work by McKenna, Yalvac, and Light examined how to create collaborative partnerships between engineering faculty and learning scientists to encourage collaborative, reflective, and improved teaching. They suggest, "An extension of this work would be to examine the trajectory of change in teaching approaches, that is, to investigate the process of change." (2009, 25). In our project, we examined a collaborative, reflective process grounded in teaching strategy development and collaboration with other engineering faculty with an interest in improving and refining teaching. Within the framework described by Henderson, Beach, and Finkelstein (2012), our project is primarily within the "Reflective Teachers" category where instructor learning communities were created for reflection about practice. The facilitators supported the work of individuals within the community as well as reflecting about their own practice. We engaged faculty in collaboration and reflection about teaching through small teaching development groups. Building these groups gives faculty a resource to reflect about their teaching and gives the university a framework for encouraging and supporting sustained instructional innovation.

The motivations for engaging in teaching development vary for faculty members. Some studies examined the motivations and influences that can play a role in whether faculty seek to learn more about their teaching (Bouwma-Gearhart 2012; Huber and Hutchings 2005) or engage in educational research – practice cycles (Matusovich et al. 2014). Negative influences include low teaching evaluations, feeling overwhelmed by teaching a class early in their career, or nervousness about appearing incompetent in front of students (Bouwma–Gearhart 2012). On the other hand, positive motivators include finding other colleagues interested in scholarly teaching and engaging with questions about students' learning (Huber and Hutchings 2005). The department and university culture around the role of teaching significantly impacts career advancement (Jamieson and Lohmann 2012). Bouwma-Gearhart pointed to a particular need for instructors to feel supported and safe discussing new ideas for teaching in the professional development setting (2012). For these reasons, in our model, we were careful that the intervention would be more informal (rather than a formal workshop or seminar about teaching). We wanted to capitalize on informal networks or relationships that might exist in a department to encourage conversations about teaching (Borrego and Henderson 2014).

TEACHING DEVELOPMENT GROUP STRUCTURE

Drawing on research from K-12 education as well as the teaching development literature for STEM in higher education, the researchers proposed an initial teaching development model. The design

of the model attempted to be sensitive to the time constraints of faculty work as well as creating a comfortable setting for instructors to talk about their teaching. We also wanted the leaders to create groups that fit within their department culture.

Design Principles

Design principles are a core feature of a design-based research framework. As stated by Anderson and Shattuck, "Designs evolve from and lead to the development of practical design principles, patterns, and/or grounded theorizing." (p. 17, 2012). We adopted two guiding principles to start the project. These principles evolved and expanded over the life of the project as we learned more about how the groups functioned. Our first guiding principle is that teaching development activity needs to be meaningfully grounded in the concerns of the participants (Henderson and Dancy 2011; Loucks-Horsley et al. 2010; McDonald and Cater-Steel 2017) and must respond to the participants' needs. For our teaching design teams, we sought instructors interested in exploring how to increase student interaction and engagement. We also expected the teaching strategies themselves to be emergent (Henderson and Dancy 2011), meaning that we did not prescribe particular strategies or teaching practices beyond the broad definition of "interactive teaching" so that participants identified their own strategies workable in their own teaching settings. Faculty had a multitude of practical questions about incorporating such interactive teaching strategies, e.g., whether to grade or assess student work and what kinds of tasks are useful. The instructors then integrated the development activities in their regular teaching. Jamieson and Lohmann propose that research projects in education need to create connections between research results and the concerns of instructors in the classroom (2009). Our project bridged this cycle by both supporting the development of personally meaningful teaching strategies, analyzing a framework for structuring teaching design groups, and meeting instructors at their current concerns and teaching dilemmas.

The second guiding principle is that teaching development (and learning in general) is most effective when teachers (or in our case, instructors) collaborate so they can learn from each other's experiences. Just as we advocate for students to learn and construct knowledge about engineering and science practice in teams, instructors should develop their understanding of designing teaching collaboratively. This is supported by other research about faculty development that demonstrates that having a collaborator or critical friend (particularly a collaborator with knowledge of educational practices) is beneficial (e.g., Addis et al. 2013; Frost et al. 2018; Winslow, Skubik-Peplaski, and Burkett 2017). McKenna, Yalvac and Light (2009) coordinated collaborations between instructors and faculty members in the learning sciences to develop teaching strategies, tools, assessments and resources consistent with the *How People Learn* framework (Bransford, Brown, and Cocking 2000). The more engaged faculty were in a reflection

process (including data collection and dissemination of results) with a colleague with expertise in the learning sciences, the greater the impact on their teaching. In other teaching development efforts, there is a focus on the use of professional learning communities or communities of practice (Wenger 1999; McDonald and Cater-Steel 2017) designed to develop knowledge and practice collaboratively.

Group Structure

The foundational structure of the teaching development groups was to be an ongoing, small group focused on teaching and developing knowledge about teaching. Our groups are situated within the broader literature about learning communities for teaching development (O. S. Anderson and Finelli 2014; Finelli, Daly, and Richardson 2014; Layne et al. 2002; Wenger 1999; Wenger, McDermott, and Snyder 2002; Zemke and Zemke 2014).“Reflective practice” is a term used in K-12 teaching development to describe how teachers need to plan instruction and also to analyze what happened after the class in order to improve their teaching (Schon 1983; Loucks-Horsley et al. 2010). There is no one-size-fits-all solution for teaching and learning. Teachers continuously adapt and refine techniques for different courses. In this sense, teaching is a dynamic process within the classroom as instructors learn and evolve as teachers over their careers. We designed the ongoing small group model to provide consistent, ongoing support for instructors attempting new teaching strategies in their classrooms. Groups combined ongoing meetings with other resources about teaching to learn more about interactive teaching strategies and methods (e.g., Ambrose et al. 2010; Mahajan 2009).

Group Leader and Participant Recruitment

Using the two guidelines (meaningfulness to participants and collaborative teaching development) as a framework to launch the teaching development groups, the researchers first recruited group leaders from four different universities; the group leaders then recruited instructors from engineering, science and math departments at their own universities to spend approximately one year in a teaching development group. One feature of the design was to make it flexible enough that logistics and needs could be customized for different contexts but also bounded enough that the discussion would encourage development of interactive teaching strategies. Each member of the group (including the group leader) selected a teaching strategy to attempt in a current or upcoming class. The only criterion was that strategies needed to encourage interactive teaching and learning or some type of formative assessment. These strategies took a variety of forms from short, in-class problems to summaries of readings for a graduate course (M. A. Hjalmarson et al. 2013).

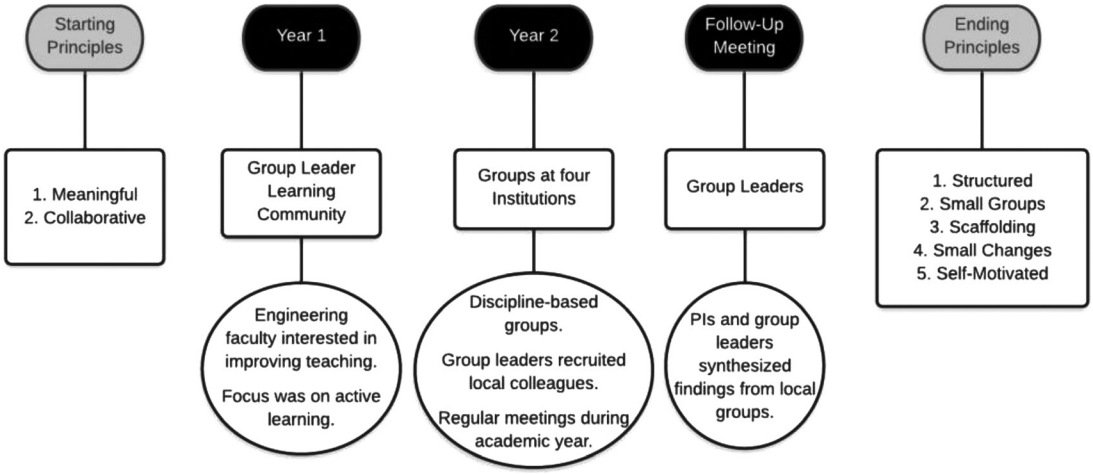

Figure 1. Project Overview.

IMPLEMENTATION AND PARTICIPANTS

The previous section explained the structure of the groups, and in this section we provide more detail about the implementation process. Figure 1 gives an overview of the entire project including our starting and ending principles and the structures for each year of the project. The data analysis and collection over the two years of the project informed the evolution of the original two starting principles into the ending principles described later in this paper. To explain how we arrived at the ending principles, we provide more detail about the group structures, data collection and analysis.

In year one of the project, the team leaders participated in a one-year cycle of a teaching development group in order to have an understanding of the types of discussions that were possible and to gather resources from each other. Year one started with a daylong, in-person organizational meeting. In year two, each team leader recruited and led a teaching development group at their own institution. Following year two, the team leaders re-convened in a meeting to discuss their groups, their perceptions of the process, and to share ideas for future work.

Year 1: Group Leader Learning Community

In the first year of the project, four electrical engineering professors (the eventual group leaders, all co-authors on this paper) and the two organizers (the first two authors on this paper) began with a daylong introductory meeting about the project and then held monthly phone conferences to go

through one cycle of attempting a new teaching strategy and reflecting on their experience using that strategy. They also wrote a two-page memo describing the strategy. The goal of the first year was to have the group leaders experience the small group professional development process before leading a group of their own. The group of faculty members was recruited because they were already trying interactive teaching strategies and had been using strategies such as in-class problems and small group work for several years. The instructors represented a range of institutions (e.g., Carnegie classifications from *Doctoral with Highest Research Activity* through *Special Focus Four Year*), and also represent a range of roles (e.g., from professor of the practice to a full professor). The group knew each other from prior collaborations, so we had built-in trust and rapport from the start of the project. The researchers wanted potential group leaders who were engaged in thinking about their teaching, motivated to develop their teaching, and willing to take some risks in the classroom. The group leaders were given stipends for their participation in this work.

Year 2: Groups at Four Different Institutions

In year two, each group leader recruited instructors at their own institution to participate in institution-based groups. Some recruited potential participants through informal networks and relationships while others recruited through formal university structures (e.g., a university center for teaching development). Groups used resources such as a books (e.g., Ambrose et al. 2010) to support the instructors' learning about interactive teaching strategies. Group members were encouraged to write design memos about teaching strategies they tried, and members received stipends if they submitted these memos. We encouraged local flexibility in terms of meeting schedules and timing in order to be responsive to institutional culture and to have an understanding of how the teaching development model might operate in different settings.

Very early on, the question arose about how important it was for the participants to be close to the leader's own discipline. While we encouraged them to start with engineering faculty, we did not limit the groups to only engineering. We were more interested in finding STEM faculty (or graduate students) invested in developing their teaching practice than in finding only engineering faculty. We emphasized the importance of recruiting people who were interested and motivated over those from a particular discipline within STEM. We encouraged recruitment of participants who were interested in teaching development and interactive teaching or interested in trying new strategies as early adopters (Rogers 2003). However, restricting the recruitment pool to STEM instructors, rather than opening it up to instructors from all disciplines, maintained the sense of similar concerns and issues that might come up in different courses. Returning to Rogers' diffusion of innovations model, he describes the role of communicating about innovations with people who have similar ideas, background, and concerns (2003). For Wenger's community of practice framework, there needs to be a

Table 1. Group Participant Descriptions.

Institution	Faculty Rank	Disciplines
A – Private	All participants held teaching-focused positions (n=4)	Civil, Electrical, Mechanical
B – Private	Participants from multiple ranks but all were tenured/tenure-track (n=6)	Electrical, Chemistry, Math
C – Public	Mix of tenure-track/tenured and teaching-focused faculty (n=3)	Electrical, Bioengineering
D – Public	Included tenured/tenure-track faculty and one graduate teaching assistant (doctoral) (n=4)	Electrical, Physics

common sense of practice that can guide the discussion within the learning community (1999). For instance, balancing procedural knowledge of algorithms for students with developing conceptual understanding is a common concern across STEM fields. Particularly at a small institution, it may be necessary to be open to a variety of STEM fields in early groups. Ultimately, the majority of the study participants were from engineering disciplines, but there was also representation from mathematics, physics, and chemistry (see table 1 for details about the group participants.

Group Leader Meetings

Throughout the project, we held conference calls on a near-monthly basis with the group leaders. However, to provide more intensive discussion at the beginning and the end of the project, we also held two daylong, face-to-face meetings that served as book-ends for organizing the group leaders. At the start of the project, we held a kick-off meeting to discuss the goals of the project and organize our efforts. At the end of year 2, the researchers organized an in-person wrap-up meeting of all the group leaders to discuss what happened in their groups and what they learned.

DATA COLLECTION & ANALYSIS

We collected and analyzed qualitative data in order to understand the nature of the groups as they evolved and to capture more detailed information about the implementation process. We investigated how the groups supported teaching development with a relatively small number of faculty; hence, a qualitative approach was appropriate for describing the phenomenon and pointing to some directions for further investigation. This is consistent with studies of the process of diffusion of innovation (Rogers, 2003). Instructors employed active learning strategies already known to have positive impacts on students' learning (Freeman et al. 2014), so documenting students' learning was not our priority in this work. In addition, students came from such a diverse set of classes (e.g., undergraduate to graduate level, different institution types) that comparisons of students' learning would not be meaningful.

Group Leaders

The meetings we had with the group leaders constituted the primary source of data for this study. However, a follow-up questionnaire with group members approximately six months after the groups' formal work concluded provided additional data about the participants' perceptions of the teaching development groups. From the group leaders, we collected meeting notes; also, each group leader wrote a narrative describing their group's work together and how they structured their activity.

The researchers took notes during the daylong kick-off meeting, conference calls and at the wrap-up meeting at the end of the project. At the daylong meeting and during each of these conference calls, Google Docs was used for note taking that was as close to transcription as possible (e.g. including comment attribution and attempting to be as close to the speakers' own words as possible). Table 2 shows a sample of these notes; the code (italicized text) and the associated comment are included. Google Docs also allowed the call participants to see the notes and make edits where they felt it was appropriate in order to have an accurate record of the meetings. Members of the team found the notes helpful as a record during and after the conference calls. These meeting notes were then qualitatively coded by one of the researchers using a grounded thematic coding process (Strauss and Corbin 1997) to understand the topics of discussion related to teaching, students' learning, pedagogical content knowledge, and the teaching development groups. This process relied on first coding comments using the broad themes and then consolidating to the most critical themes. Descriptions of the principles were also generated by the group leaders themselves within the final wrap-up meeting that is described later.

Table 2. Meeting Notes and Coding.

Meeting Notes Comments in italics indicate comments particularly relevant to the code	Coding
Leader X: Our group here is myself and four other faculty from the engineering school. Easier to implement staying within engineering *([lists four disciplines])*. Have met once. Laid out expectations. Talked about what they've done - some active learning things, not a whole lot of formative assessment. Enthusiastic about doing this and building a community here was appealing to them. One of the major outcomes here could be connecting to each other and getting conversations going. Get community formed and established. Once a month meeting through spring and fall. Getting the Ambrose book as a foundation for discussion. Our next meeting scheduled in March and again in April. Implementation will take place in fall. Everyone will have identified course they're teaching and activities to try out. Continue talking about activities in the fall, be support for each other. Write down what they've done and what they've tried. Only had one meeting.	Talking about connections and support for each other
Leader Y: What did you do to recruit?	
Leader X: These are people I have worked with. All people who are [focused on teaching]. Knew they would be predisposed and interested in this kind of thing because of position. Only person in ECE have worked together before. They haven't done a whole lot of these things. Part of it was not knowing how to get started. If we can build our community, it will be nice to have contact in each department. Wanted spectrum across the school.	Talking about motivation and recruitment, Creating connections

The group leaders participated in a final two-day in-person meeting to review how the groups at the local institutions worked together and to synthesize experiences. The first day focused on logistical issues, group design, and different teaching strategies considered. At the start of the first day, each leader described their local group and how it operated. The discussion flowed between conversation about teaching and conversation about the groups themselves as we examined recruitment and participation of members. For instance, how willing were instructors to participate and what innovations in interactive teaching were they interested in attempting? Following the conversation, group leaders were asked to write about their team in a short (2–5 page) narrative responding to the suggested questions below (used as a writing prompt but not a strict outline). The goal was to capture, in the leaders' own words, their understanding and knowledge about the progress of the group at their institution. While the group leaders were working on their narratives, the researchers began creating a list of principles for development groups (discussed later in this paper) based on key themes and features that arose in the morning discussion. In the afternoon, the group leaders reviewed this list for validity. We then continued to discuss their teaching development groups, and they made small revisions to the list of principles. As a result, the principles were generated by the group leaders themselves. The following day, the group leaders read each other's narratives in order to provide feedback, ask questions, and consider items that might be useful in their own narratives. We examined three major topics: lessons learned by the group leaders (with particular attention to their role as facilitator), the use of the two-page memos as a mechanism for documenting and discussing teaching, and how formative assessment was discussed in the groups.

Group Participant Survey

In order to capture the participants' views of the teaching development groups, we conducted an online survey approximately six months after the groups had concluded their work. Of the 17 participants, 8 replied to the survey. They were given a small ($15) gift card for completing the survey. At least one participant from each institution involved responded to the survey. The respondents' courses ranged from introductory undergraduate level through upper-level (junior/senior) courses. Their self-reported background with formative assessment and interactive teaching ranged from not very familiar to very familiar. We focused the survey on finding out what strategies they had tried in their classes and what benefits and challenges they found in the teaching development groups. For instance, we asked about one characteristic they would retain in the development groups, one thing they would change, and both the benefits and challenges they found in being part of a teaching development group. Given the small number of participants, excerpts from their responses are used where appropriate below, but identifying information (e.g., institution type, department) has been removed for anonymity.

Case Study Interview

To provide a more in-depth analysis of the participant experience, we also conducted two interviews with an engineering faculty member, one six months after the end of the group and a second follow-up interview at the end of the next semester, to understand in more depth how his teaching was evolving and how the discussions with his colleagues influenced changes in his teaching. This faculty member was selected not necessarily as a typical case, but to illustrate what might be possible from participation in a learning community and to explore the process of change in teaching over a long period of time. He was also selected because he had participated in a previous book study group, so we knew from personal experience how much his teaching had changed over time.

RESULTS

Our research question was about the principles for designing teaching development groups and the key features to consider when implementing teaching development groups. Our results expand on our original two principles (collaboration and meaningfulness) to generate five principles that are more focused than the original principles guiding the groups at the outset (see figure 1). We also describe the individual case of one faculty member to illustrate these principles.

Five 'S' Principles for Teaching Development Groups

During the wrap-up meeting, the researchers formulated the following five principles for creating successful teaching development groups: small groups, small changes, scaffolding, self-motivated and structured (see Table 3) (Hjalmarson and Nelson 2014; Hjalmarson, Nelson, and Lorie 2015; Nelson and Hjalmarson 2015). We characterize our results as design principles consistent with a design

Table 3. Five "S" Principles for Teaching Development Groups.

Principle	Description
Small Groups	Groups should be small (about five people) both for logistical reasons (easier scheduling) and to allow greater participation and engagement of all the members in the community.
Small Changes	Small, lower risk changes made incrementally accumulate to substantial changes over time. This allows instructors to make change at a comfortable pace.
Self-Motivation	Participation was voluntary. Participants had an interest in interactive teaching and might have experience using interactive pedagogies
Scaffolding Knowledge	Resources that provide sample strategies and help instructors learn about the theory and rationales for changing teaching need to be provided and discussed.
Structured	Groups have a facilitator/organizer who helps set meeting schedule, sets an agenda/goals, and facilitates the group's discussion.

research perspective (Kelly 2006; 2014). As Anderson and Shattuck explain, design principles are not decontextualized but rather should operate within the contexts in which they are applied (2012). We began this project with two guiding principles (meaningfulness and collaboration) that were then refined and augmented into the resulting principles described here. These principles summarize the recommendations that grew out of the discussion by the group leaders regarding how their groups had developed over time. The group leaders reviewed them and provided feedback. We describe them as principles in order to identify salient features that may take on different forms at different institutions but which were identified as guiding ideas that facilitated successful group interaction.

Small Groups

First and foremost, teaching development groups should be small (about five people) both for logistical reasons (easier scheduling) and to allow greater participation and engagement of all the members. A key feature of the small groups is forming a supportive community for discussing teaching. For example, one leader wrote about small group formation, "The group was excited to form a community that would regularly discuss topics of common interest and be supportive of each other's' teaching-related efforts." (Group Leader Narrative) The small size can be especially helpful for developing relationships in groups where the members don't know each other at the outset. There is also more accountability for participating in meetings. The discussions of readings, resources, and strategies are a key component of teaching development, and the small group size creates a more comfortable environment for those discussions. Confidentiality is also crucial so participants can share and receive feedback about what they are trying in their classrooms without feeling vulnerable. In addition, the same rationale for small group work with students' learning applies to instructors' learning. Namely, learning is supported by social interaction and the ability to discuss concepts (Rogers 2003; Wenger 1999). As one participant noted as a benefit of the groups in our survey, "Gives me a chance to test the approach in a more formal way, and interact with people doing other things and learn from them." This sense of testability of a new teaching strategy and the ability to get feedback is an important support for making changes to teaching (Rogers 2003). Overall, based on the follow-up survey, the participants were largely engaged in the process of learning about their teaching and trying new teaching strategies. Evidence of this is that 6 of 8 survey respondents reported they were still meeting with their group members, and one participant stated they would change "The duration of the program. I am already missing it."

Small Changes

The second principle, small changes to practice, defines what types of teaching change are encouraged. While some instructors are ready to overhaul a whole class, many instructors may not be ready or comfortable making large changes. However, small, lower risk changes made incrementally

accumulate to substantial changes over time. The slow pace can then be supported as instructors receive positive feedback about their teaching (e.g., from students via teaching evaluations). For example, one strategy presented was the use of two-minute questions in class. This can be a comfortable, low risk strategy both because designing and assessing the problems should not take too much time and because it does not reduce class time significantly. Another strategy was to ask students to use an algorithm they had learned to solve an example problem rather than having the instructor present the solution. Again, this requires minimal preparation on the part of the instructor and is a manageable in-class activity. In the sense of diffusion of innovations, the changes need to be considered "doable" by the instructors (Rogers 2003). As introductory techniques for interactive instruction and formative assessment, these small changes could lead to larger undertakings.

An important element of small changes is that they present only small risk for instructor and students. One risk in shifting to interactive teaching is that students may be resistant to working on problems in class. For the instructor, the risks are that the students won't participate, they will lose control of the class, they give up time used for covering content, and they are trying something in class they have never done before. There is also risk in having students share solutions that the instructor must then analyze and respond to at the moment rather than having time to prepare. By implementing small changes over time, a cycle of positive feedback about instructional change can begin as instructors and students have positive experiences of interactive classrooms. A related element of the risk involved is time, both in class and out of class. Participants in the survey consistently responded that time was a challenge for them in trying interactive teaching strategies; 6 of 8 mentioned some aspect of lack of time in their response about challenges they faced. Small changes typically require smaller time investments for preparation and execution. This is consistent with Rogers' notion of "trialability" where users need to be able to test an innovation and see how it works in their context (2003). The community of practice structure provides support and feedback for taking such risks.

Scaffolding Knowledge

Many instructors in higher education may have limited knowledge of innovative, formative teaching practices based on research about teaching and learning in engineering. Resources that provide sample strategies and help instructors learn about the theory and rationales for changing teaching need to be provided and discussed. The researchers anticipated that early group meetings might need more scaffolding in terms of resources than later meetings and that the meetings would evolve over time. It is typical for communities of practice to incorporate resources and have some evolution in structure as their practice changes over time (Wenger 1999). Consistent with other study results, teaching development should include increasing knowledge of research-based teaching and learning

information (Engin and Atkinson 2015; Henderson and Dancy 2011; McKenna, Yalvac, and Light 2009). In our case, each teaching development group participant was given a book about teaching (e.g., Ambrose et al. 2010) or used other external resources such as MIT OpenCourseware (Mahajan 2009). STEM faculty also valued data-based research about teaching practices and theories (quantitative data was helpful) to provide justification for making a change to teaching. While resources should be provided to help instructors understand the education theory and reasoning behind interactive teaching and formative assessment, a focus on theory must be balanced with practical strategies usable in the university STEM classroom. Other faculty learning community research also points to the practical nature of the discussion for participants (Engin and Atkinson 2015). For example, theory and data supporting collaborative learning was combined with practical information about how to structure and create a collaborative learning classroom. The resources served as discussion starters (i.e., the scaffolding) for engaging the instructors in thinking about their own teaching practice and considering what they might try with their own students.

Self-Motivation

In the wrap-up meeting discussion, the researchers observed that the element of instructor self-motivation to engage in teaching development arose from two perspectives. Instructors drawn to participating in the groups are often either trying interactive strategies already but are unaware of the education research that supports their ideas on teaching, or they are seeking a network of people who are also interested in teaching development. This principle is linked to scaffolding in the sense that instructors may have tried an active learning strategy or may know they should be incorporating more active learning in their teaching; however, they may not know how to begin or may need support from colleagues to persist and improve their active teaching strategies. In all of the groups, participation was voluntary, and the team leaders often personally recruited instructors known to have an interest in teaching. As one team leader wrote, "They were each interested in improving their teaching practice, and in improving how much their students are learning." Such small group formats are unlikely to be successful as mandatory activities for instructors (especially first-year faculty) given that it takes time in planning and implementation to commit to even a small change in teaching and to participate in a group. Wenger also describes communities of practice (or learning communities) as voluntary (1999).

By design, our project recruited instructors who had an interest in interactive teaching and might have experience using interactive pedagogies. The goal in this project was not to be their first introduction to interactive teaching, but rather to help them continue conversations and support for interactive teaching and learning. This is a distinction between our work and other faculty development projects that may focus more on initial exposure to interactive teaching. As a result, the instructors had self-motivation

and were already interested in interactive teaching when they came to the group. This did not preclude discussion of what interactive teaching might look like in different courses.

Structured Groups

The role of structure in successful groups was a common theme among group leaders. In some cases, leaders believed that their group had sufficient structure to be successful, while in others the leader felt that the group would have benefitted from more structure. The group participants also noted that structure was a beneficial element. When asked (on a survey) one thing not to change about the teaching development groups, one instructor stated "Despite the difficulty of finding the time for the meetings, it was actually good to have a fixed timetable to keep myself accountable." Having the group leader as a facilitator to organize meetings, select resources, and start discussions was one critical element of the structure. Leaders felt that the group was more effective if meetings were scheduled in advance and tasks were planned (e.g., when will design and implementation happen). It also helped to know products were expected that required reflection and explanation of the teaching strategy. In addition, having an agenda and taking minutes were identified as helpful for accomplishing tasks. Groups also needed to set goals and identify group composition (e.g., new faculty, senior faculty, new to interactive teaching or not, within department or between departments) in order to guide structure and organization. However, within the group structure, the meetings themselves were a space for an open and flexible discussion of teaching strategies within the confines of the goals and expectations of the groups. The group leaders reported that their main role in the meeting was to start the discussion.

The Case of Kyle

One of our participants serves as a notable example of how the five principles above play out in practice over a multi-year period. Kyle was selected for a case study not because he was necessarily typical of participants in the project, but rather because he illustrates the kinds of changes that are possible. His case also allowed us to understand how long change might take. We had first met Kyle as part of a prior informal learning community about teaching, so we were aware of the start of his trajectory and how much change he had made both prior to and during this project. As a result, he was a good candidate for deeper analysis. The first author interviewed Kyle[1] six months and twelve months after the group concluded their formal meetings to find out how participation in the group influenced his teaching and what teaching strategies he continued to incorporate. These interviews illuminate the process of change that can happen with the support of a group of colleagues and knowledgeable others (in his case, a friend who was a high school teacher). For Kyle, one of his first

[1] Kyle is a pseudonym used for one of the participants.

encounters with interactive teaching was via an informal book club that read *How Learning Works: Seven Research-Based Teaching Strategies* (Ambrose et al. 2010). This book club was housed in his department and took place prior to the grant-funded teaching development groups. Following the conclusion of the book club, he joined the teaching development group that formed in his department. At the start of the book club, Kyle taught using primarily lecture, and his main concern was covering all of the content. Over a two-year period, he slowly shifted toward more interactive teaching because conversations with other people, in his words,

> "...made me aware that simply lecturing to students, while it made me feel good about what I was able to cover and accomplish and the structure I was able to bring, maybe wasn't the right way to go about teaching and I had to step back and consider what the point of teaching was. It wasn't about what I could convey to them so much as what they could learn in the classroom, so that's when our conversations started to revolve around what we could do in our classrooms to improve the learning." (First interview)

Ultimately, Kyle's goal was to decrease his lecturing and increase students' time working on problems in class. Part of his rationale came from what he saw as a problem with lecture in supporting students who were at different places in their understanding of the content. He designed lectures to cover everything in enough detail for the students who knew the least, but he realized that he bored the students who were further ahead. He also began to realize the impossibility of explaining everything in exhaustive detail. So, his focus began to shift from exhaustive explanations to creating a learning environment where students could work more at their own pace.

Structured, Scaffolded and Small Groups

These three principles describe the organization of the group itself. Kyle's group was small — about 5 faculty members from his department who met regularly over the course of a year. The "structured" element of the group included both the regular meetings (every few weeks) and the external resources to launch discussion. The leader of the group scaffolded the group by including materials about undergraduate teaching from MIT OpenCourseWare (Mahajan 2009). The group included novices in interactive teaching as well as members more experienced with this practice. Both the group leader and a senior member had many years of experience incorporating interactive problems in their classes. Hence, the use of in-class problems was not new to the department even if not all instructors were using it. The group discussed teaching, active learning, and different teaching strategies. However, given the use of in-class problems by his colleagues, it was not surprising that Kyle selected this strategy to use in his class. In his interviews, Kyle referenced these colleagues

as influencing his decisions to make changes to his teaching and to include in-class problems. For example, he described these conversations in his first interview as follows.

> "And it also, like I said, we were talking to [the group leader] in our meetings, it enlightened me to some of the things that needed to be done in the classroom to get through to them. The purposes of the things we were doing. The exercises are meant to engage the students. If they want to review them ahead of time and understand or figure out their answers ahead of time, that's a great thing. I think the whole purpose is to improve the learning and the retention of the material."

Small Changes Over Multiple Semesters

Kyle's evolution as an instructor illustrates the guiding principle that the groups should support small changes over time rather than requiring major overhauls to courses. Kyle's first change was to include multiple-choice questions in his lectures using an iClicker system. Over multiple semesters, he began lecturing less and using problems more. He started to provide review materials on the course website so students could learn about the material before class and spend class time working on problems.

> "So whereas, with the previous iteration of the class, I didn't have an opportunity to go and address individual students because there was limited time and the rest of the students were waiting on those students so I had to move on to the newer material. I'm hoping that by covering everything at once and allowing the students that know or understand the material to move through the exercises on their own, I can now then address the portion of the class that needs help without feeling that I'm slowing everybody else down." (First interview)

Throughout this change process, Kyle also responded to student feedback and requests. At first, he was not including the in-class problems in the online resources for class because he wanted students to solve them in class. But, a request from a student to post the in-class problems before class made him re-think this decision and reflect on the overall goal for what he was trying to accomplish with these problems. He described an epiphany; the student's request reminded him of the overall purpose for in-class problems and what he wanted students to learn.

> I guess one of the students…asked me "I'd really appreciate it if you'd post the slides a day ahead of time so that I could review them, so that I could go through the questions and see if I can figure them out." And, my initial response to myself, not to her directly was "that kind of defeats the purpose of having in-class exercises. You're supposed to do them in class." It was some fleeting thought and I suddenly stopped and kind of chuckled to myself

> and said "no, the actual purpose of the in-class exercises is to help them learn and if they want to learn independently, so much the better." So, isn't that the point of this? Is to get them involved in their own education? It was at that point that I realized that sometimes you have to stop, and while you think you have a reason for doing something, you have to think about what the real reason is for doing something. (First interview)

Teaching development groups need to be aware that these changes are a long-term process. This design process of planning-testing-revising takes multiple semesters. In his second interview, Kyle describes the course revision process as first identifying the important concepts he wants to teach and the order in which he wants to teach them. After he feels comfortable with the content, he can create in-class problem sets for the students. He also approaches the transition to having more in-class problems as a course-by-course process. He might still use lecture as a primary mode of instruction in one class but work to create and use in-class problems in another class. Creating, implementing and revising problems requires multiple semesters of design. As Kyle described the process of trying new exercises to get at concepts, he explained it as:

> I'm just finding that in certain cases, it's not really the multiple-choice, it's not knowing what question to ask to get them to think about this concept. "I want you to understand this". Well, I can say it to you but what do I ask you to make you come up with that? And, there are times where I'm like I can't figure out what question to ask. I've tried and I've said "well how bout this".... well that's not the right question. "How bout that?" And then yes, once I come up with question, what are the answers that I can provide that don't just give away the answer immediately?

Self-Motivation: Enjoying Teaching and Focusing on Learning

As described previously, self-motivation is a guiding principle of the teaching development groups in terms of instructors voluntarily participating. The goal in the groups was to support interactive teaching broadly and to encourage faculty to adopt interactive strategies that were most comfortable for them rather than prescribing specific strategies for them to use. Self-motivated strategy selection also led to increased engagement in teaching by the instructor. A strong theme in both interviews with Kyle was his enjoyment of his new mode of teaching and his feeling that students were more engaged in their learning. In his first interview, he explained it as "I definitely felt like I was having more fun because the students were doing something as opposed to just sitting there. I got bored after the first couple semesters of teaching them and I'm still getting bored in my other class where I'm just lecturing to the students and I don't even know if they're with me or not." At the second interview, he described his most recent class session as "It was really just me talking for an hour which I'm now beginning to

loathe because I've started to really enjoy the other way of doing things." This is an important theme because while much of the research focuses on the benefits for students of interactive teaching, Kyle is an example of the benefits for the instructor. This is particularly critical for instructors like Kyle who have a large teaching load. To motivate continued reflection and improvement, the process of making teaching more interactive should engage not only the students but also the instructor.

CONCLUSION AND IMPLICATIONS

Our flexible structure for teaching development groups can accommodate local needs at different institutions while operating within a set of guiding principles we found to be critical to group success and instructor engagement. By design, the groups operated within a broad theme of interactive teaching and encouraged participants to incorporate new teaching strategies as appropriate for their class. At the same time, the approach also supports faculty where they are in teaching. This developmental approach to changes in teaching fosters a design perspective that incorporates cycles of planning-implementation-revision as instructors design the teaching and learning environment. One of our primary goals was to consider how to support faculty as they tried new strategies in their classes. This was not a question of changing instructor beliefs about teaching necessarily, but rather helping them explore new ways of teaching that better supported student engagement in learning. There is often a gap between learning about a strategy and having support for trying that strategy. We hoped to fill that gap with a professional learning community model.

Our principles capture some of the elements of professional learning communities. Wenger's (1999) original argument for a community focused on a particular domain (in this case, teaching engineering) and common practices (in this case, interactive teaching) was also significant to sustaining group members' interest. Other projects have emphasized the role of faculty interest and self-motivation for participation (Engin and Atkinson 2015; Kezar, Gehrke, and Bernstein-Sierra 2017; Ma et al. 2019).

A continuing challenge is considering how to scale up a teaching development model to engage more instructors in more departments. In our case, the first thing we did was to identify group leaders we knew were interested in teaching development and who would recruit their colleagues to participate. In this model, each leader was responsible for a single group in their home department, maintaining a reasonable level of commitment for group leaders. In some of our other work, we have explored lessons learned from scaling up (Nelson, Hjalmarson, Samaras, and Bland, 2020), in particular noting the value participants find in discipline-based communities of teaching development and the importance of structure in sustaining the groups. While the number of groups was limited by the number of group leaders available, we felt it was important that the leaders be closely connected to

the department as part of a discipline-based effort. As members of these groups have shared their experiences across campus, faculty from other departments across the institution have approached us about forming a group in their own disciplines. Similarly to thinking about small changes in teaching that accumulate over time, it may be that efforts on a campus start with a few groups and then grow over time to other departments. In this sense, the grass-roots nature of this model is important.

Examining the case of one instructor reveals how the teaching process can evolve over multiple semesters. The case study also illuminates the importance of instructor willingness to change and openness to feedback from colleagues and students. When considering realistic expectations for a faculty development experience, we must recognize that the innovations may need a few semesters to take hold. This is consistent with other projects that have sustained communities over multiple semesters or years (Engin and Atkinson 2015; Ma et al. 2019).

For further investigation, we suggest broadening the application of the model to additional settings and other disciplines. The groups in this project were created around STEM disciplines and an interest in interactive teaching; however, small groups could be created supporting the adoption of a specific teaching strategy or goal across classes and disciplines. Some participants mentioned increasing the diversity of disciplines represented within a group to enhance the conversation. Anecdotally, some participants found it valuable to learn what was occurring in other STEM classes (e.g., prerequisites to their own) to find out what types of strategies students may have already experienced (e.g., using clickers in other classes). Limiting the teaching development groups to within STEM disciplines could support the development of teaching both in engineering courses and in related pre-requisites and co-requisites.

We continue to have questions about creating groups for faculty who have different levels of expertise in interactive teaching. Our participants represented a range of background knowledge of interactive teaching strategies, and this diversity may have benefited them in terms of sharing ideas and getting feedback about their teaching. However, we have additional questions such as: how do new groups form in an institution? Also, what is the role of the group leader in scaffolding and supporting their colleagues over time? The ending principles may also evolve in other contexts. In short, while this study represents a step along the path of creating interactive, engaging classrooms, there is still much to be learned.

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