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A Journey Toward Mastery Teaching: STEM Faculty Engagement in a Year-Long Faculty Learning Community

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As part of an institutional focus on STEM student success, a group of STEM faculty participated in a year-long faculty learning community (FLC) to explore and adopt research-based best practice in their teaching. The authors assessed the effectiveness of the FLC in influencing faculty perceptions about teaching and increasing their use of best teaching practices. Their research design used pre- and post-analysis of participants' teaching logs, classroom observations, and a survey instrument that probed attitudes toward teaching and learning. Data analysis shows that the sustained support provided by the FLC increased faculty knowledge of best teaching practices and catalyzed faculty to try new pedagogical and assessment approaches. However, over the year of the FLC experience, only small shifts were observed in faculty perceptions and practice, as measured by a survey and a descriptive observation protocol, respectively. Results suggest the experience primarily supported modest faculty exploration of new strategies.

Introduction

There is a fundamental and problematic paradox in higher education: University faculty members generally are more effective when they engage in high quality, best practices teaching, yet many have never formally studied how people learn or been supported in their efforts to adopt highly effective pedagogy (Centra, 1976; Flick, Sadri, Morrell, Wainwright, & Schepige, 2009; Momsen, Long, Wyse, & Ebert-May, 2010). Outside of education and some related social science domains, university faculty members typically do not study teaching and learning as part of their preparation or ongoing professional activities (Sunal et al., 2001). The primary focus and preparation of most university faculty is on domain-specific research, publishing, and grant writing, activities that rarely include explicit and structured reflection on teaching and learning (Fox, 1992; Henderson & Dancy, 2007). As a result, many university faculty members adopt teaching practices similar to those that they experienced as students.

Teaching practices among faculty members from science, technology, engineering, and mathematics (STEM) disciplines is of particular importance due to growth in STEM careers (Carnevale, Smith, & Melton, 2011). The demand for a STEM-prepared workforce places a burden on STEM faculty effectively to teach and prepare a growing diversity of students. This is most effectively accomplished with a deep knowledge of best instructional practices and an understanding of how people learn (National Research Council, 1999a).

Traditionally, STEM faculty members have relied on the use of didactic instruction, a lecture-and-listen approach to teaching and learning, as their primary pedagogical method (Lindblom-Ylanne, Trigwell, Nevgi, & Ashwin, 2006; Lueddeke, 2003). While it is not uncommon for STEM faculty members to be dissatisfied with the level of learning that their students achieve in lecture-based courses (Handelsman et al., 2004), many faculty remain unaware or choose to ignore the wealth of research-based best practices that have been proven to promote deep learning in STEM disciplines (Fairweather, 2008; Froyd, 2008; Handelsman et al., 2004). Still others accept the value of student-centered pedagogies and report implementing them, but direct observation suggests that a gap exists between faculty perceptions and the extent of their actual implementation of these strategies (Ebert-May et al., 2011) or that they abandon them after a limited implementation. The challenges associated with shifting STEM faculty practice toward more student-centered pedagogies motivated us to study the influence of a year-long faculty learning community (FLC) professional development program on the participating STEM faculty.

The STEM FLC we studied was focused broadly around the theme of "student success in STEM," in contrast to previously described STEM FLCs that were more specifically focused on adoption of new pedagogy, such as active learning (for example, see Smith, 2009). The FLC we studied did not have a predetermined "curriculum." Rather, individual teaching projects, topics, and issues discussed in the FLC were determined by the faculty participants, and the participants took an active and dynamic role in co-leading the group, as suggested by Cox (2003). Because of the breadth of issues and ideas explored within the FLC, we gathered a range of data to expose potential changes in our participants' perceptions about teaching, classroom practice, and reflection on their practice. Our study is also comprehensive in that we took measurements at both the beginning and end of the year in order to better understand the impact of the FLC on the participants.

Before delving into the research project and findings, we lay the groundwork for our study by reviewing the relevant literature in faculty professional development and teaching and learning in STEM. We then present our methods and study results, followed by a discussion of our findings and the implications for STEM faculty professional development. We close with the potential limitations of the study and concluding remarks that frame the study in the broader realm of STEM faculty professional development.

Review of Literature

Learning and Teaching in STEM

Students frequently enter STEM degree programs needing to acquire, conceptualize, and connect vast amounts of foundational knowledge (Momsen et al., 2010). In response, STEM faculty members perceive their job to be filling up students with fundamental knowledge, which goal remains a primary influence for the structure and curriculum of lower-division undergraduate STEM courses (Ebert-May et al., 2011; Sunal et al., 2001). Unfortunately, if students are not provided with opportunities to place their knowledge in context, conceptualize concepts, apply their knowledge creatively, and build a sense of connection and sense of belonging in their chosen STEM field, they are less likely to be academically successful and more likely to leave STEM fields (Froyd, 2008; Marra et al., 2012; Momsen et al., 2010; National Research Council, 1999b; Seymour & Hewitt, 1997).

STEM faculty awareness of the most effective ways to engage students in learning foundational concepts is constrained. Most faculty members find it acceptable to perpetuate an approach that they navigated successfully even if it does not maximize learning (Ebert-May et al., 2011; Sunal et al., 2001). The use of pedagogical practices that are misaligned with how people most learn effectively can prevent faculty from appropriately scaffolding learning experiences to promote the acquisition, application, and transfer of knowledge (Detterman & Sternberg, 1996). For example, a lack of understanding of the wide variety of misconceptions and alternative conceptions that students bring to STEM courses (Driver, Squires, Rushworth, & Wood-Robinson, 1994; Duit, 2007) limits the ability of faculty to craft instruction to support student conceptual change (Sinatra & Pintrich, 2003). Addressing these problems is critical to student success, because in order to be successful as a STEM major, students must build on a deep understanding of STEM course content. Faculty awareness of the justification and implementation of the best practices associated with successfully engaging STEM students in learning were major themes of the FLC we studied.

Faculty Change

A number of extrinsic and intrinsic variables may lead faculty to consider changing their instructional practice (Bouwma-Gearhart, 2011; DeHaan, 2005; Ebert-May et al., 2011; Henderson, Beach, & Finkelstein, 2011). Extrinsic pressures from peers, from students, or from administration may prompt faculty members to seek and use new approaches in teaching. Changes in instructional practice may also be initiated by intrinsic factors, as individuals become more dissatisfied with their current practice or more aware of alternative pedagogical strategies. Research on faculty change has revealed several barriers that may impede faculty adoption and internalization of new instructional practices (Henderson et al., 2011; Sunal et al., 2001). These barriers include the expectation of productivity in domain specific research and scholarship, time constraints, and limited access to meaningful and appropriate pedagogical professional development.

Even though calls for systematic change in STEM faculty teaching may increase instructors' awareness and interest in changing their practice (Handelsman et al., 2004; National Research Council, 1999b), the actual process of change is most likely to be determined at the individual level (Bouwma-Gearhart, 2011; Henderson, Dancy, & Niewiadomska-Bugaj, 2012; Walker, Cotner, Baepler, & Decker, 2008). Polich (2008) reports that faculty are more likely to make changes when new pedagogies are consistent with an individual's beliefs about learning and teaching. Certain structures and support may be necessary for STEM faculty to develop a basis for reflective analysis of their teaching that leads to changed pedagogy

(Henderson et al., 2012; Raubenheimer, 2004). For example, collaboration with other STEM faculty members and educational specialists may play an important role in promoting STEM faculty to consider new pedagogical approaches (Harwood, 2004). Further, Henderson et al. (2012) indicate that some faculty-related variables (for instance, engagement in reading teaching-related journals, attending workshops on teaching, satisfaction with meeting instructional goals) are potential indicators of adopting and retaining change in teaching practice. Regardless, Goldston and colleagues (2004) report that changing teaching practice is a complex process, and the recent review of faculty change by Henderson et al. (2011) demonstrates that our understanding of how best to support faculty change is far from complete.

Faculty change has been described as occurring in stages (Paulsen & Feldman, 1995). For example, in order to make sustained changes, faculty members first must go through a period of "unfreezing," during which they are challenged (or challenge themselves) to consider making changes to their teaching. "Unfreezing" is followed by a "cognitive restructuring" phase, during which faculty acquire and experiment with new ways of thinking and behaving with respect to their teaching. Finally, "refreezing" is the stage during which new beliefs and behaviors are solidified and sustained for the long run. These are similar to stages described for career changes: exploration, trial, establishment, and mastery (Hall & Chandler, 2007). In these models, there is a period of exploration before new behaviors and identities are adopted. However, there is no guarantee that exploration will lead to the sustained adoption of the new identities, perspectives, or practices. Because of the relative stability of faculty teaching practices (Russell & Martin, 2007) and the need for change (Handelsman et al., 2004), there is justification for ongoing experimentation with and research on STEM faculty professional development that is designed to enhance the quality of teaching practices.

Faculty Professional Development and Faculty Learning Communities

Most STEM faculty members engage in professional development that is associated with their area of research expertise. Expectations that STEM faculty will seek out professional development associated with teaching and learning are not widespread in higher education. That said, there is increasing awareness and support for engaging STEM faculty in professional development related to teaching and learning (Sunal, Wright, & Day, 2004), as their effectiveness is critical to resolving some of the STEM pipeline issues (Carnevale et al., 2011).

The teaching and learning professional development for university faculty members may be structured to address gaps in pedagogical knowledge, enhance understanding of how to align teaching with how people learn, or shift perspectives and practices to be more effective and satisfying (Caffarella & Zin, 1999). The most common form of professional development offerings for faculty are relatively brief workshops or seminars offered through university centers for teaching and learning or at professional organization conferences (Caffarella & Zin, 1999). Although these one-time offerings may increase some basic knowledge of teaching and learning, they are not likely to result in dramatic and sustained shifts in perceptions and practices of teaching (Connolly & Millar, 2006; Henderson et al., 2011).

Faculty learning communities (FLCs) have emerged to address the need for faculty development opportunities to achieve significant and sustained shifts in teaching perceptions and practice. An FLC, as defined by Cox and colleagues (2001, 2004), is a group of 8-12 faculty who engage in a year-long facilitated program designed to enhance teaching and learning. Research based on self-reports (Beach & Cox, 2009) and case studies (Dees et al., 2009) suggests that faculty participation in FLCs increases interest in the teaching process, enhances understanding and influence of the scholarship of teaching and learning, and increases reflective practice. Faculty also report implementing specific teaching and learning approaches as a result of their FLC participation, and they say these efforts lead to increases in student learning.

The recent focus on the professional development needs of STEM faculty has led to the formation of FLCs composed of faculty members from a single STEM discipline (Sirum, Madigan, & Klionsky, 2009) or across STEM disciplines (O'Meara, 2005, 2007). STEM FLCs described in the literature generally have focused on the adoption of a specific practice or strategy, such as active learning, with a planned curriculum coordinated and led by a facilitator. Research indicates that participants tend to join STEM FLCs with some interest in teaching innovation and, in some cases, are already implementing or experimenting with different teaching techniques. Regardless, evidence suggests that faculty participation in STEM FLCs supports their implementation of new teaching strategies and engagement in critical reflection (O'Meara, 2005, 2007; Sirum & Madigan, 2010; Smith et al., 2008). In addition, some of the STEM FLCs described in the literature involved faculty for more than a year, indicating that long-term engagement may be important for fostering change (Smith et al., 2008; Sirum & Madigan, 2010). Consistent with Henderson et al. (2011), these reports suggest STEM faculty members are mostly likely to undergo significant and sustained shifts in their perceptions and practices of teaching when they engage in long-term professional development emphasizing the promotion of pedagogical reflection, understanding of learning, and exploration of instructional practice.

Methods

Our research was motivated by the desire to study how participation in a year-long STEM FLC influenced the knowledge and perceptions of learning for the STEM faculty participants. We sought to expose evidence of how the participating faculty internalized and utilized best instructional practices. Guiding our investigation were the following questions:

1. How did the participants' perceptions about teaching and their practice change over the course of the FLC?
2. Did the participants' instructional practices change over the course of the FLC?

We anticipated that involvement in the FLC would shift members' perceptions of teaching and learning toward becoming more student-centered, accompanied by an increase their understanding of active-learning pedagogies. The shift would manifest itself in notable changes in pedagogical practice, reflecting a greater level of student involvement and increased engagement in higher-order thinking and problem solving.

Participants

The focus of our study was a cohort of eight STEM faculty members selected from a pool of applicants to be part of an FLC focused on enhancing student success in STEM learning. One of the faculty members dropped out of the group after one semester due to workload constraints. The remaining seven participants (three females and four males) had appointments in chemistry, physics, mathematics, materials science, and mechanical engineering. They had either tenure-track or full-time lecturer appointments. They had held faculty positions in higher education for 0 to 13 years.

Structure of the Faculty Learning Community

The FLC held a two-day retreat in August before the fall semester commenced and then met every other week for the duration of fall and spring semester. Although there was a facilitator for the group, it was expected that responsibility for leading meetings would rotate among the participants. The focus for the meetings, chosen by the participants, was on specific topics relevant to STEM teaching and learning. Examples of topics explored include best-practice pedagogies, frameworks for student development, strategies for assessment, misconceptions in STEM, institutional student success data, and how STEM disciplines frame the context for teaching and learning. Each 1-hour-and-45-minute meeting used discussion, presentation, reflection, sharing, and readings to engage in deep exploration of the various STEM teaching and learning topics. Each participant completed a modest individual teaching project focused on student learning in his or her course. The FLC would be classified as "emergent" (Henderson et al., 2011), meaning that the desired final state was to be determined by faculty participants as part of the change process. Likewise, its focus was on developing reflective teachers, supporting the notion that faculty development places faculty in a "strong position to choose appropriately" if their reflective practice is supported (Henderson et al., 2011).

Instruments and Protocols

Survey of Teaching and Learning Perceptions and Practices

We adapted and adopted elements from extant instruments (Brawner, Felder, Allen, & Brent, 2001; Keeton, 2004) to develop an assessment of teaching practices and perceptions of teaching and learning. Our instrument consisted of 21 items and included statements to which participants were asked to respond on a 5-point Likert scale, with 1 representing *strongly disagree* and 5 *strongly agree*. Five items (1-3, 15, and 21) probed attitudes or ideas about teaching, such as, "I am concerned about students' attitudes toward my teaching" and "I feel responsible for helping all the students in my course to be successful." The remaining items generally were focused on each respondent's teaching practice and were phrased in such a way that *strongly agree* suggested the respondent was using best practices in his or her teaching. These items included, "I am always trying something different in my teaching" and "I work to use teaching practices which have been shown to be effective in supporting student learning." Because of the nature of the instrument, which comprised a combination of unique, adopted, and adapted items, the validity was assumed, and the reliability had yet to be established. Rather than using the data to conduct inferential statistics, however, our goal was to report the collected data descriptively. Further, our sample size ($N = 7$) lacked sufficient statistical power to make a reliability analysis calculation meaningful.

Teaching Logs

We used "teaching logs" as a way of capturing an array of participant perceptions of teaching and learning. Teaching logs are analogous to pedagogical diaries and are an effective means of gathering data characteristic of participants' reflections on their teaching and students' learning, perceptions of their practice, and general thoughts about pedagogy. Participants were provided a four-part prompt for each log entry: (a) learning objectives for the week, (b) examples of things that have gone well with respect to my teaching and student learning in my course(s), (c) examples of things that I would like to change with respect to my teaching and student learning in my course(s), and (d) insights I have gained with respect to my teaching and student learning in my course(s). Participants were requested to write reflections in their logs on a daily basis.

Teaching Observations

To document our participants' teaching practice, we used the *Reform Teaching Observation Protocol* (RTOP) developed by Piburn and colleagues (2000). The RTOP was chosen because its design reflects the theoretical framework of inquiry-oriented teaching, and its implementation provides for a systematic assessment of learner-centered teaching. The goal of the FLC we studied was to support faculty understanding and adoption of practices that better support student learning. Thus, the fact that the RTOP has been shown to be predictive of student achievement provided another reason to use this instrument (Lawson et al., 2002). The RTOP was developed and vetted to document teaching practice in four domains: class design, class content, communication, and the student-teacher relationship. The RTOP allowed us systematically to document participants' instructional practices and, specifically, their implementation of reformed pedagogical practice (that is, student centered learning). We made minor changes to vocabulary in some items to reflect the higher education environment. Researchers using the instrument score items such as "Students were actively engaged in thought-provoking activities that often involved the critical assessment of procedures" on a 5-point scale ranging from 0 (*never occurred*) to 4 (*very descriptive*). The reliability and validity of the instrument has been established by the developers (Piburn et al., 2000). The items generally describe best practices in teaching. An "ideal" score would be a 4 on every item. (A more complete description of the meaning of the RTOP score is found in Ebert-May et al., 2011.)

Data Collection and Analysis Procedures

Survey of Teaching and Learning Perceptions and Practice

We surveyed the FLC participants at the beginning of the academic year using a paper version of our perceptions of learning and teaching practices survey. We instructed the participants to use a unique code as an identifier to maintain anonymity while allowing us to track participation. We used the same survey to post-assess our participants at the end of the academic year. Data are presented from the six participants who completed both the pre- and post-survey.

Teaching Logs

Participants were requested to keep records weekly throughout the academic year and were encouraged but not required to use the prompt structure. Most participants kept a regular log, though not all made weekly entries. Several used an alternative format rather than using the log we provided, though they maintained a spirit of reflection about teaching and learning. We collected the teaching logs at the end of the academic year for analysis. Six participants submitted their logs to be analyzed as part of this study. We analyzed these data using a combination of *a priori* and emergent theme coding using a content analysis framework (Miles & Huberman, 1984). The *a priori* codings were extracted from the teaching logs prompts provided to the participants. The emergent codes were developed from trends that emerged as we reviewed the teaching logs.

Teaching Observations

We observed and video recorded the faculty members' teaching once in the fall semester, shortly after the FLC commenced, and again near the end of the spring semester, at the conclusion of the FLC. We used the RTOP systematically to structure the documentation of our observations. Faculty members were not involved in the collection of the data and were not part of the research team, but rather served as participants in this research project.

To establish inter-rater reliability, we had an experienced researcher work with a novice field researcher, both observing two of the participants teach a class session (all were about 1-1.5 hours long), scoring their observations using the RTOP. Following the observations, we compared RTOP scores and discussed differences. We repeated the process by having both the experienced and novice field researchers observe and RTOP score the teaching of another FLC participant. Again, scores were compared and differences discussed. We then conducted a final round of joint-researcher observation and RTOP scoring with yet another participant teaching a course session, and compared and discussed differences. After each round the differences diminished, and the consistency in RTOP scores increased, which, after four rounds of observations, resulted in nearly full agreement (more than 90%) in scoring. Once the scoring of the novice researcher and expert was consistent, the novice was tasked with the teaching observations and RTOP scoring for the other participants in the fall semester, and for all participants in the spring semester. For participants observed by both novice and expert, average scores were used for the pre-observation. One of the participants was not observed in the spring. The data presented are for the six participants for both fall and spring observations.

Results

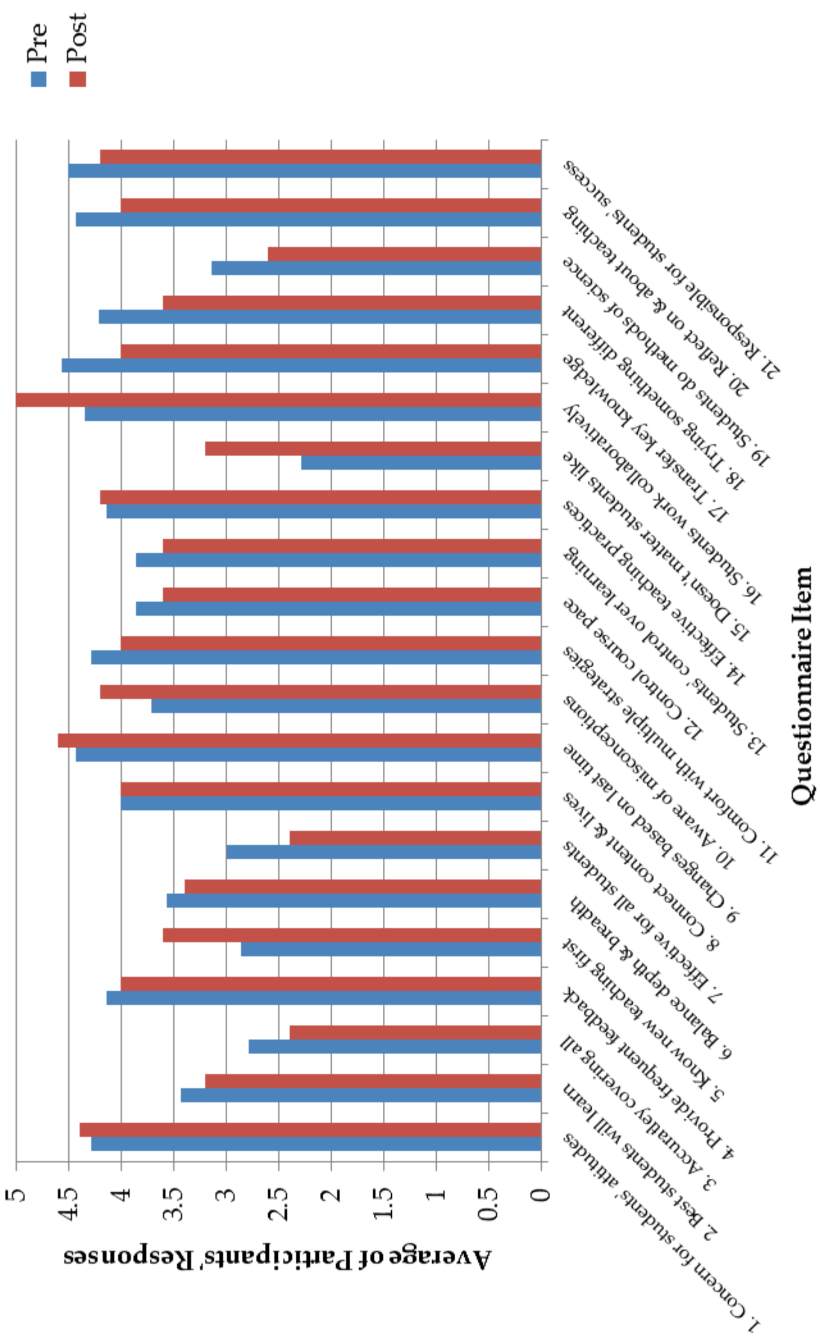
Teaching and Learning Perceptions and Practice

Our first research question asked, "*How did the participants' perceptions about teaching and their practice change over the course of the FLC?*" To answer this question, we descriptively analyzed the participants' responses to our perception of learning and practice of teaching instrument. Figure 1 shows participants' pre- and post-FLC average responses to each item. The broad contours of responses did not change markedly from pre- to post-, suggesting that faculty reports of their perceptions and classroom interaction did not change substantially during the year of the FLC. In addition, the average on most items are in the *agree* range, both pre- and post-, suggesting that faculty began the year agreeing that they use many best practices and, broadly speaking, ended the year in a similar position.

In order better to understand the nuances of participants' perceptions, we examined their pre-FLC average responses showing the highest level of disagreement. Item 15, showing the most disagreement, stated, "It doesn't matter if students like the course as long as they learn the material." A relatively high level of disagreement indicates that as a group the faculty began the FLC with the perception that is important for students to like a course as well as learn the course content. Our analysis also exposed a few other items that were below neutral (in the *disagree* region) in the participants' pre-FLC responses. These included participants' perceptions about covering material as being the purpose of teaching (item 3), about the need to know a lot about a new approach before using it in instruction (item 5), and about whether the course and their teaching style appeared to be effective for all of their students (item 7).

On the opposite end of the pre-FLC averages, we found the highest

Figure 1
Pre- and Post-FLC Average Participant Response
From Perceptions of Teaching and Learning Survey



average agreement with the items describing that participants focus their teaching on transferring key knowledge to their students (item 17), that they take responsibility for student success in the course (item 21), and that they adjust a course based on students' prior learning (item 9). This suggests that the participants began the year concerned about their students' success and felt that they had influence over or should take responsibility for students learning in their courses.

We continued our analysis by examining shifts in the participants' post-FLC responses relative to their pre-FLC responses (see Figure 1). Again, because of the small sample size, we conducted this analysis descriptively, focusing on items with an average Likert-scale shift of at least 0.5. We noted four items with which respondents registered less agreement at the end of the year than at the start. Participants were less likely to define teaching as transferring key knowledge (item 17) and less likely to indicate they were always trying something different in their teaching (item 18). The data show a move from a neutral stand to one of disagreement with the perception that participants' teaching is effective for all students (item 7) and that their course engages students in the methods of science (item 19). Four items had average post-FLC responses that shifted upwards between fall and spring. Participants indicated greater agreement with statements indicating that they were aware of misconceptions that get in the way of learning (item 10) and that they encouraged students to work collaboratively (item 16). Responses shifted from disagree to modest agreement with the notions that participants preferred to know a lot about how a new teaching practice would work before trying it (Item 5) and that their students do not have to like a course as long as they learn the material (Item 15). Despite this last shift, there was almost no change in how concerned participants were with students' attitudes toward their teaching (item 1).

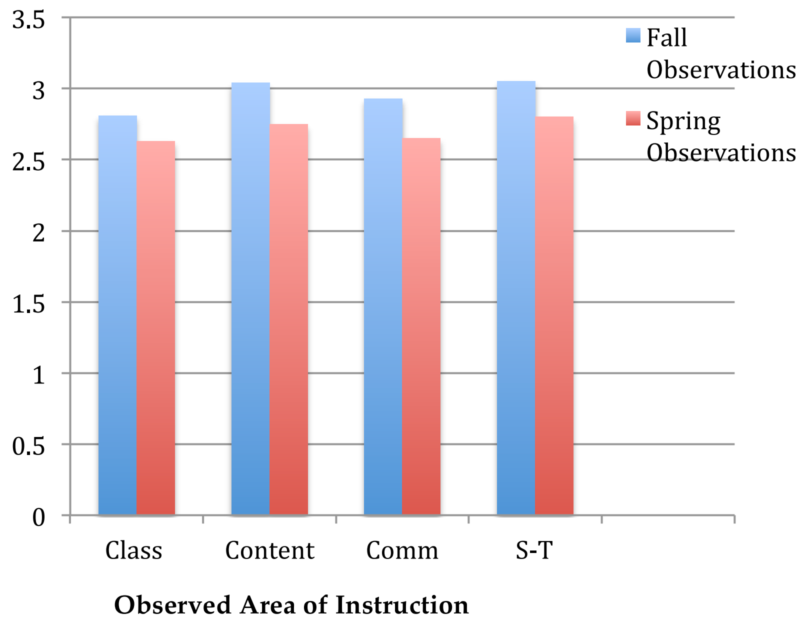
Actual Classroom Practice

Our second research question asked, *"Did the participants' teaching practices change over the course of year-long faculty learning community?* To answer this question, we descriptively examined the pre and post-FLC RTOP scores. We also conducted a content analysis of the participants' teaching logs.

RTOP Scores

The average RTOP domain scores (Piburn et al., 2000) are presented in Figure 2. The pre-FLC RTOP average scores are above middle for each of

Figure 2
Average RTOP Scores on Each of Four Domains Based on Observations for Fall (Early-FLC) and Spring (Nearly Post-FLC)



Note. "Design" is the domain related to class design and implementation, "Content" includes both propositional and procedural knowledge, "Comm" captures the communication in the classroom, and "S-T" is related to the student-teacher relationship.

the four subscales (the maximum score was 4), suggesting that the average practices for each of the four domains was more likely to be *descriptive* of participants' teaching than to be *never occurring* in their teaching. Further, the instrument successfully differentiated between those faculty who began the year already engaged in the use of a number of best-practice pedagogies (for example, active learning) and those whose approach would be described as "mostly lecture." The lowest individual composite score (the sum of the four domains; the maximum possible score was 16) from the fall observation was a 10.1, while the highest was a 13.7 (data not shown).

The average data show small negative shifts from pre- to post-observation on all four of the subscales, with movement toward the statements being less descriptive of participants' instructional practices. This result is based on one individual's composite score staying the same, and the remaining five instructors' composite scores decreasing. The spring individual composite scores ranged from 9.3 to 12.3, with nearly all faculty remaining in the same ordinal position within the scoring (for example, the lowest-scoring faculty member was the same person in the fall and spring; the highest-scoring faculty member also was the same person in the fall and spring). On the four individual domain scores, only one score from one faculty member increased between fall and spring; the rest stayed the same or decreased (data not shown). These data suggest that participants were observed using fewer best-practice pedagogies at the end of the year than at the beginning.

Teaching Logs

The teaching logs provide additional insight into the participants' practice. Content analysis of the teaching logs (Miles & Huberman, 1984) exposed a wide range of instructional concerns, successes, and insights into learning and revealed 11 teaching and learning themes (see Table 1). Although there were varying degrees of alignment between the participants' comments and the themes, they all reflected an important or critical aspect of teaching practice or insight into student learning. The most frequently identified theme was associated with participants' reflection on an aspect of their teaching that they would like to change. The other identified themes fell into two broad categories: reflections about classroom practice (including strategies that were new to the instructor) and reflections based on classroom assessment. Several of the themes are explicitly associated with pedagogical approaches that were new to the faculty member. For example, nearly all participants reflected positively about a new method they had tried yet expressed frustration about the difficulty in "coverage" of material due to changes in how they were spending class time. The themes associated with classroom assessment indicate that faculty members were paying close attention to how their explorations of new approaches were working. For example, faculty identified that struggling with problems was useful for students' learning.

Discussion

Our data show that the group of STEM faculty members who were recruited and applied to participate in the FLC came with some knowl-

Table 1
Teaching Log Themes

Theme (Number of Faculty Responding)	*Representative Response*
Teaching Practice	
Reflected on how they would change things for the next time or on an aspect that they would like to change. (6)	"A handful of students (3-4) dominate student participation —comments and questions. Today I was too heavy-handed in shutting down one of them."
Reflected positively about a new method that they tried. (5)	"I think the applied problem is helping to keep the material more connected and relevant, and it makes a bigger difference than I would have thought."
Implemented the use of group work. (5)	"I had students work in groups and get to agreement and compare answers"
Expressed frustration in not being able to cover the breadth of material that they have in the past; experienced being behind. (5)	"Time management with the new method is still an issue." "I am getting worried that I may not manage to cover everything, and I do not know what to skip to get the more important parts."
Found success in increasing student understanding through introducing real-world problems or events to drive instruction. (3)	"Students in both classes worked on the real world problems and got familiar with the format I want them to use."

Classroom Assessment	
Found that the best learning occurs for students when they struggle with problems. (4)	"I still need to shift more of the problem solving over to the students. Watching is fine, but not much learning occurs. Learning occurs while the students are struggling with the problems. Maybe I can use the clickers to do some of this."
Tried to predict student performance based on in-class observations. (4)	"The weakest student was the quietest, but some quiet students did really well."
Observed higher-level questioning or questioning beyond the material from students. (3)	"Students had all kinds of questions, from things I thought they should know to questions that showed they were clearly thinking beyond the material."
Observed that when students develop their understanding of the content, it is more powerful that when students receive their instruction through lecture. (3)	"I think the applied problem is helping to keep the material more connected and relevant, and it makes a bigger difference than I would have thought."
Noticed that an added benefit of student discussions and/or problem solving is that it helps identify misconceptions. (3)	"Students solved a problem, and throughout this exercise they asked questions and brought up their misconceptions."
Reflected on students' apparent satisfaction with class. (3)	"I notice that the environment of the classroom is one where, I believe, most students feel safe asking and answering questions, and testing out their theories."

edge of best-practice teaching, as evidenced by their responses to the fall survey. Based on observations of their practice in the fall, the degree to which the faculty were implementing these best practices varied, but all were using at least some effective strategies for supporting student learning. The overall tenor of the teaching logs underscored that this group of faculty were open to exploration and to reflecting on their practice.

While the participants communicated generally consistent perceptions of teaching and learning and their practice over the year of their participation in the FLC, as measured by our survey, there were a few notable exceptions. Some of the changes are consistent with the FLC's focus on an exploration of the teaching and learning literature. The group read about and discussed factors that support and present barriers to learning for students as well as about a variety of pedagogical strategies that can be used in STEM teaching. Their increased tendency to encourage collaborative learning, which was also documented in their teaching logs, and their awareness of misconceptions about course content are consistent with this interpretation. Their decreased sense that their teaching was effective for all students likely reflects an increased knowledge of what is required to support student learning. Further, the participants increased their knowledge of the range of pedagogical strategies from which instructors can choose. The increased awareness likely broadened their horizons and contributed to an increased desire to know about how an approach will work before trying it. The increased awareness also may have led to decreases in the participants' sense that they were consistently "trying something different," and a decreased sense that their approaches were genuinely engaging students in the methods of science.

Other changes observed in the survey data suggest subtle shifts in the ways faculty perceived the purpose of their teaching. The shift away from a definition of teaching as transferring key knowledge to students is consistent with comments in the teaching logs acknowledging that students need to struggle with material and construct their own understanding. The decreased sense that it doesn't matter whether students like the course as long as they learn the material could be linked to resistance to change on the part of the faculty participants, which translates into a dismissal of student input. However, because the teaching logs and group discussions did not provide any evidence of resistance to change, we believe this result is more likely linked to the FLC's focus on student learning as a measure of successful teaching (as opposed to a focus on student satisfaction alone, as evidenced by course evaluations). In fact, another survey item showed the faculty remained concerned about student attitudes toward their teaching.

Because the goal of this FLC was to change faculty members' teaching practice, we had expected that participating members should demonstrate a dramatic increase in the use of reformed practices in their teaching. However, our direct observations do not indicate that this occurred. In fact, if there was any change, the observation data show a small decrease in the use of reform practices. A number of possible explanations exist for these data. Our second round of observations, in late spring semester, may have taken place on days during which the faculty were using more traditional pedagogical practices and, therefore, were not representative of their experimentation with new approaches. Faculty might have been less likely to employ new teaching strategies near the end of a semester due to pressure to "cover material" before the semester was done. It is also possible that this second observation captured faculty in a state of exhaustion, unable to sustain a consistent effort towards changed teaching practice. While the RTOP is clearly capable of differentiating between faculty using more and fewer reform-practice pedagogies, the changed quantity and quality of pedagogical exploration used by individuals in the study may have been too subtle to register with the RTOP protocol. In contrast to the RTOP results, the themes identified in the teaching logs very clearly reflect an exploration of both new teaching practice, an increased degree of reflective practice, and at least an informal focus on assessment of the impact of their new approaches. However, the misalignment may be reflective of the findings of Ebert-May and colleagues (2011), in which there is a disconnect between faculty self-report of reform practice and their actual classroom implementation.

Taken together, these results suggest that the experience of the FLC supported modest shifts in attitudes and practice for the faculty participants. While the changes were not large, there is evidence that the engagement in discussions and reflections on different aspects of teaching and learning effectively altered STEM faculty members' perceptions of and plans for instructional practices. We are encouraged by our findings, but also realize that more needs to be done to alter STEM faculty pedagogy. Our results are consistent with research that shows initiating change in STEM faculty teaching practices requires time, structure, and support (Raubenheimer, 2004). The data suggest that the STEM FLC may have a priming effect, preparing participants for the longer-term process of conceptual change and internalization of reformed teaching practices. Most of the faculty in our group are likely to fall into the "cognitive restructuring" stage of change (Paulsen & Feldman, 1995) or the "trial" stage of exploring a new identity as a teacher (Hall & Chandler, 2007). It remains to be seen if they continue to work at the implementation of changed practice, moving forward in their journey toward mastery teaching. Unfortunately, it is likely that without continued support, a portion of them will abandon their efforts toward student-centered teaching (Henderson et al., 2012).

It is interesting to consider whether modifications to the FLC could increase the pace, magnitude, or sustainability of faculty change. Recent recommendations suggest that successful STEM faculty development includes both reflective practice, which was the focus of the FLC we studied, and direct feedback to instructors about their practice, which was informal in this FLC (Henderson et al., 2011). Thus, the addition of explicit coaching and feedback is recommended for future FLC participants and is worth exploring. The engagement in coaching may diminish the conditions in which faculty learn about best practices but largely are left alone to implement them (Ebert-May et al., 2011).

Because FLC implementation varies with institutional context, it is important that there be investigations of multiple contexts to contribute effectively to our collective understanding of the influence of faculty development programs, particularly for STEM faculty (Kucsera & Svinicki, 2010). The exploration of a variety of professional development methods in different contexts for promoting STEM faculty members' use of best teaching practices is most certainly a fruitful direction for future research.

Limitations

The first limitation of our project was the restricted number of observations made of the faculty members' teaching. Two observations of each of the faculty members may have been insufficient to capture shifts in their teaching practices. Multiple observations each semester may have allowed us to capture a broader range of reformed teaching practices. Further, the RTOP may not be adequate to capture the changes in practice the faculty did make, suggesting additional instruments may be needed effectively to capture more early, and presumably subtle, shifts in reform teaching practices.

Another limitation of our study is associated with the nature of self-report data. As with any self-report research, we cannot determine how accurately the participants' descriptions of their practice reflect their actual practice. They may have *thought* that reformed teaching is a good idea and *believed* they were exploring it, but struggled to implement it effectively, using approaches that, upon observation, resembled their traditional teaching more than something new. The lack of alignment between perceptions and practice of teaching has been documented (Ebert-May et al., 2011; Olafson & Schraw, 2006) and may have occurred in our study.

The fact that the faculty were self-selected to participate in this experience means that the conclusions we might draw from the effectiveness of this kind of FLC experience may not be applicable to faculty in general.

The final limitation is the duration of our study. The FLC may have catalyzed the change process of the faculty members, and the evidence of their changed practice may come to fruition later, as they continue to reflect on their teaching and experiment with new pedagogical approaches. The longitudinal study (beyond the one year of this research) of STEM faculty pedagogical development following their engagement in FLCs certainly merits additional investigation.

Conclusions

We studied a faculty learning community that was designed to enhance the participating STEM faculty members' pedagogy and knowledge of teaching and learning. Although we detected some shifts in their perceptions, and some evidence of change in teaching, these shifts did not transfer to short-term substantial changes in practice. While substantial change in pedagogy is a long-term process, an FLC can provide needed support and can generate a priming effect that ultimately may lead to significant and sustained changes in the teaching of participating STEM faculty.

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