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Implementing Pedagogical Change in Introductory Biology Courses Through the Use of Faculty Learning Communities

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Abstract
Recent national reports have indicated a need for significant changes in science higher education, with the inclusion of more studentcentered learning. However, substantial barriers to change exist. These include a lack of faculty awareness and understanding of appropriate pedagogical approaches, large class sizes, the time commitment needed to make these changes, and lack of resources and support. At Iowa State University, the implementation of student-centered learning in introductory biology classes is being facilitated by the use of faculty learning communities (FLCs). Progress toward this goal was assessed via surveys of faculty, including both FLC participants and nonparticipants, to determine their teaching practices and attitudes toward biology education. Two years after the formation of the FLCs, a majority of FLC participants indicated that they had experimented with teaching methods and had worked to clarify learning goals for their classes. To continue these changes and promote a true cultural shift within the program, our next steps are to independently assess faculty progress toward studentcentered learning and changes in student learning gains, as well as to develop a more transparent incentive and reward system for faculty teaching.

Keywords
science higher education, faculty learning communities, student-centered learning, pedagogy

Disciplines
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Comments
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Recent national reports have indicated a need for significant changes in science higher education, with the inclusion of more student-centered learning. However, substantial barriers to change exist. These include a lack of faculty awareness and understanding of appropriate pedagogical approaches, large class sizes, the time commitment needed to make these changes, and lack of resources and support. At Iowa State University, the implementation of student-centered learning in introductory biology classes is being facilitated by the use of faculty learning communities (FLCs). Progress toward this goal was assessed via surveys of faculty, including both FLC participants and nonparticipants, to determine their teaching practices and attitudes toward biology education. Two years after the formation of the FLCs, a majority of FLC participants indicated that they had experimented with teaching methods and had worked to clarify learning goals for their classes. To continue these changes and promote a true cultural shift within the program, our next steps are to independently assess faculty progress toward student-centered learning and changes in student learning gains, as well as to develop a more transparent incentive and reward system for faculty teaching.

The President's Council of Advisors on Science and Technology (2012) called for substantial improvements in science, technology, engineering, and mathematics education, with one recommendation focused specifically on the integration of active learning into the classroom. This need has also been highlighted in the American Association for the Advancement of Science's report, *Vision and Change* (Brewer & Smith, 2011), and the National Academies' report, *Bio2010* (National Research Council, 2003). These documents cite accumulating evidence on student education that a powerful strategy to engage students in more effective learning is to minimize lecturing and shift to a student-centered, active learning (SCAL) approach (e.g., Freeman et al., 2007; Knight & Wood, 2005; Michael, 2006; Prince, 2004; reviewed in National Research Council, 2003). Pedagogical strategies that elicit student engagement during class result in greater mastery of course content than passive learning environments (Pascarella & Terenzini, 2005). Furthermore, positive changes that are inherent to active pedagogies include increased interaction between faculty and students, more formative and summative assessments, and greater feedback to students as they learn (Cuseo, 2007). The effectiveness of student-centered pedagogies is particularly acute in science courses in which the norm is frequently a lecture-based format with an emphasis on memorization rather than on understanding scientific approaches and processes (Ebert-May, Brewer, & Alled, 1997). Although the data are compelling, achieving student engagement in large classes (100+ students) is especially difficult. Instructors in these large-enrollment courses tend to rely on traditional lecture formats (Ebert-May et al., 1997; Moore, 1996; National Research Council, 1996). This article documents our university's progress toward the integration of active learning pedagogies in large-lecture courses that have been facilitated by faculty learning communities (FLCs).

Student-centered, active learning

Instructors using SCAL guide students in the construction of their own knowledge. Unlike passive lecture courses, SCAL is innately engaging as students direct their own inquiries (Postareff, Lindblom-Ylanne, & Nevgi, 2008; Samuelowicz & Bain, 2001), interacting extensively with each other and the instructor. The evaluative emphasis of the course is also shifted from being almost entirely summative to a mix of formative and summative assessments. The structure of student-centered courses is vastly different from that of instructor-centered courses and involves major changes in both materials used in class and the philosophical approach of the instructor.

Challenges

To make the transition from lecture-based to student-centered teaching, institutions, departments, and faculty need to undertake a cultural change. This undertaking is substantial. An ideological paradox exists in many science faculty members' approaches to teaching. There is a conflict between their respect for scientific findings and their own experiences as students. When shown the data supporting the efficacy of student-centered teaching over instructor-centered teaching, biology faculty are often reluctant to accept the findings because the vast majority of them were taught through lecture-based courses (Cuban, 1990; Hativa & Goodyear, 2002; Henderson & Dancy, 2007). Most faculty excelled in these instructor-centered courses (Hativa & Goodyear, 2002). Therefore, a common question is, "If it worked for me, what is wrong with lecturing as an effective means of teaching?" It has been suggested that the current faculty were top students at least in part because they learned differently than many of their peers (Hativa & Goodyear, 2002). By extension, the instructor-centered approach would therefore be ineffective for the majority of students.

Transforming an instructor-centered course to a student-centered course requires clear learning goals and major changes in class materials (Allen & Tanner, 2007). At research-intensive institutions, faculty members' contractual time assigned to teaching can be quite low, often 30% or less. The transition from lecture-based to student-centered teaching is daunting; faculty must devote time to writing class activities, learn how to write such activities, and manage a student-centered classroom often with very little support (Cohen, 1988; Henderson & Dancy, 2007; Sunal et al., 2001). With such little temporal emphasis placed on teaching, and with tenure decisions usually more heavily weighted toward research productivity, faculty's motivation to devote time and energy to improved pedagogy decreases even further (Sunal et al., 2001). Furthermore, most faculty are not trained in the design of student-centered courses (Sunal & Hodges, 1997), as they were taught via lectures and do not have any experience with student-centered learning. In fact, many may not understand exactly what student-centered learning is.

For many introductory courses, this task is especially challenging because classes often enroll more than 100 students. With recurring budget cuts and a poor economy, enrollment in biology courses is increasing and so is the size and number of large classes. For example, more than 2,700 students take introductory biology courses each year at Iowa State University (ISU). These are divided into 200–350 student sections. Between the 2010/2011 and 2011/2012 academic years, enrollment in introductory courses increased by approximately 20%. Managing classrooms of 200–350 students engaged in SCAL can be difficult, and without proper guidance, students in such environments can flounder.

Approach

To promote and support pedagogical change in introductory biology courses, biology faculty members formed FLCs. The FLCs are intellectually engaging forums for discussing current pedagogical literature, assessment tools, and what is or is not working in the classroom. A defining characteristic of FLCs is that all members are equal learners and are often focused on specific project goals (Cox, 2004). Faculty opted to use the FLC design because of the inherent collaborative nature, the propensity to elicit emergent change, and previous positive experiences with them (Cox, 2004; Layne, Froyd, Morgan, & Kenimer, 2002; Richlin & Cox, 2004). The community-oriented nature of these faculty groups also provides support for implementation of novel practices (Rogan, 2007). ISU's biology FLCs consist of 8–12 members each and meet twice per month. Participation is encouraged by a nominal stipend and by the time efficiencies that instructors have recognized through sharing ideas, information, and resources. Pedagogical changes in the introductory biology courses were not mandated by the department, college, or university but were rather a result of faculty members' desires to improve instruction.

We chose to focus on the introductory courses because of the high enrollment and the diversity of the student populations. Nonbiology, science-oriented majors constitute 72% of the enrollments. Although increased enrollment does add to the challenge of student-centered teaching, the importance of expanding the number of science majors who can contribute to the economy and society, as outlined in the President's Council of Advisors on Science and Technology (2012) report, is paramount. Pedagogical improvements to introductory courses have been shown to increase the number of students majoring in science, technology, engineering, and mathematics (Mervis, 2010; reviewed in Brewer & Smith, 2011).

Emergent change and roles of FLCs

According to Goldstein, Hazy, and Lichtenstein (2010), emergent change is accomplished by harnessing the natural development of innovations within a group (bottom up) and by the amplification of the changes to the entire organization (top down). Faculty learning communities provide the environment for bottom-up change to develop by bringing faculty members together to consider solutions to common prob-

FIGURE 1

Project objectives.

1. Introduce and familiarize faculty with the approach of improving instruction through scientific teaching. Scientific teaching is a pedagogical approach that iteratively evaluates teaching methods to enhance effectiveness (Handelsman et al., 2007).
2. Promote conversations among faculty within the Biology program, beyond those members of the FLCs, about best teaching practices.
3. Educate faculty on how to design student-centered learning activities.
4. Implement approaches to aid faculty in managing large classes with student-centered activities.

lems. Top-down change occurs when the formal structures of the university and departments are modified to use the skills and knowledge developed in the learning community to guide reform. Here, the bottom-up goals are to improve student learning and to help faculty teaching introductory biology through the sharing of resources. The university's (top-down) goals are increased enrollments and retention in science fields.

The project began with one FLC composed of 17 faculty members who teach one of the core freshman- or sophomore-level courses in biology. All faculty members teaching the introductory biology courses were invited to participate in the FLCs; there was initial involvement from our School of Education. Each of these courses serves diverse majors. After the first year, the faculty opted to form two FLCs devoted to the first-semester (Biol 211) and second-semester (Biol 212) introductory biology courses. As of the writing of this article, the Biol 211 FLC had five participants and the Biol 212 FLC had nine. Faculty participants ranged from tenured full professors to nontenured assistant professors to senior lecturers. The participants come from four life-science departments.

Objectives

The primary objective of the biology FLCs is to inspire and enable faculty-led transformation of the introductory biology courses at our university from lecture based to ones enriched with student-centered learning activities. Recognizing that this will be an iterative process, we have defined intermediate goals that are foundational to long-term success. The current study is one of formative assessment. Have our approaches helped us reach these benchmarks?

We aligned our objectives with four substantial challenges to converting science courses from instructor centered to student centered (Figure 1). These include (a) familiarizing faculty with the pedagogical approaches of scientific teaching (Saroyan & Amundsen, 2004; Seymour, 2001); (b) promoting discussions among the FLC members and their colleagues about the feasibility and appropriateness of using student-centered approaches in introductory classes (Sunal et al., 2001); (c) educating faculty on how to design these courses, including backward design, development of learning objectives, and the importance of formative and summative assessments (Sunal & Hodges, 1997); and (d) developing and assessing student-centered activities for large classes (Figure 2; Allen & Tanner, 2007; Armstrong, Chang, & Brickman, 2007).

Assessment

To monitor progress, we surveyed faculty on their practices and opinions of biology education after 2 years of biology FLCs. This survey was based on the pedagogical development challenges described by Ebert-May et al. (2011), with additional questions written by the authors (full survey available at http://www.nsta.org/college/connections.aspx). The survey originally included 5-point Likert scales, but these were condensed to 3-point scales for analyses because of ambiguities in the distinctions between *strongly agree* and *agree* and *strongly disagree* and *disagree*. Forty faculty members completed the survey—19 were current or former members of an FLC and 21 had never participated in an FLC. Survey data were not collected at the onset of the FLCs; the faculty not participating in FLCs was used for comparison.

FIGURE 2

Ongoing reforms at Iowa State University to aid faculty in managing large classes with student-centered activities.

- Increased use of clickers in large, introductory courses
- Integration of undergraduate teaching assistants into lectures to assist in facilitation of group work
- In-house grants for outside speakers on pedagogical innovation
- In-house grants for development of active learning exercises
- Collaboration on external grants for development of pedagogical tools and scholarship
- Collaboration among faculty through faculty learning communities and departmental seminars

Progress toward benchmarks

Two years after developing the biology FLCs, faculty involved have begun to transform their teaching of introductory biology courses (Figures 3 and 4). According to the view of one FLC participant, some members are quite motivated:

> I want to give [students] a lot of responsibility for their own learning. Try to facilitate that rather than just feeding them the information. I want to give them a context to apply the information that they get themselves out of the textbook.

The faculty survey supports the conclusion that faculty perceptions and practices are changing. As these data are self-reported, we recognize that each individual faculty member may define experimentation in teaching differently. However, we believe these data are informative because of the correlation between the occurrence of conversations relating to experimentation in teaching in the FLCs and the numbers of faculty reporting they have experimented with innovations in pedagogy. We asked faculty whether they had started to experiment with ways to improve their teaching.

As shown in Figure 3, 89% of faculty who participated in the FLCs were more likely to agree with the statement, "Over the past year, I have started to experiment more to improve my teaching," compared with 48% of peers who were not members ($p = .032$ [Fisher's Exact Test (FET)]). Note that 48% of non-FLC faculty members surveyed have begun to experiment more with teaching, which may suggest that changes are occurring outside of the FLC as well.

FIGURE 3

Faculty responses to the statement, "Over the past year, I have started to experiment more to improve my teaching." Fisher's Exact Test: *p* = .032. FLC = faculty learning community.

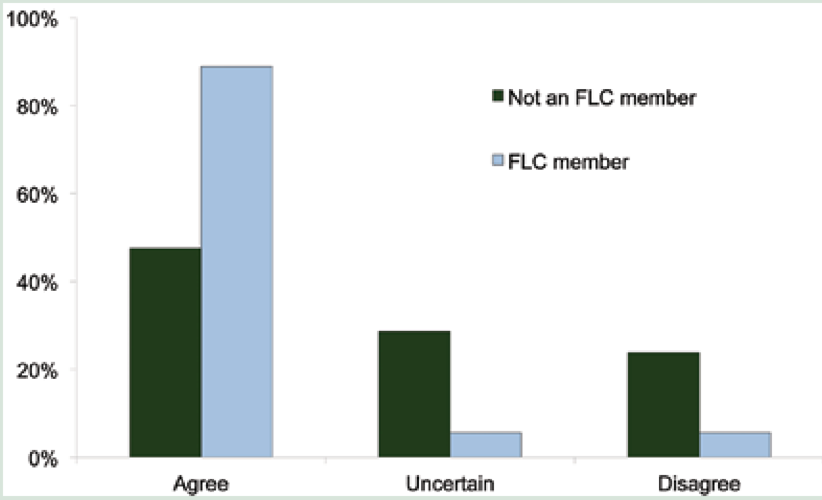
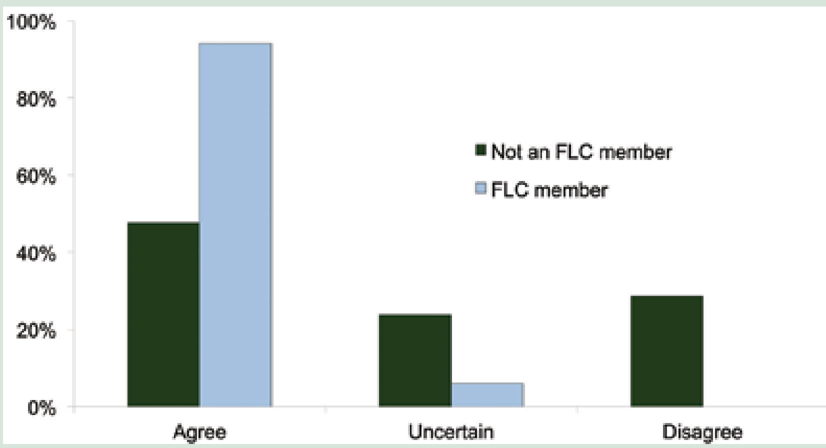


FIGURE 4

Faculty responses to the statement, "Over the past year, I have worked to clarify the learning goals of my courses." Fisher's Exact Test: *p* = .009. FLC = faculty learning community.

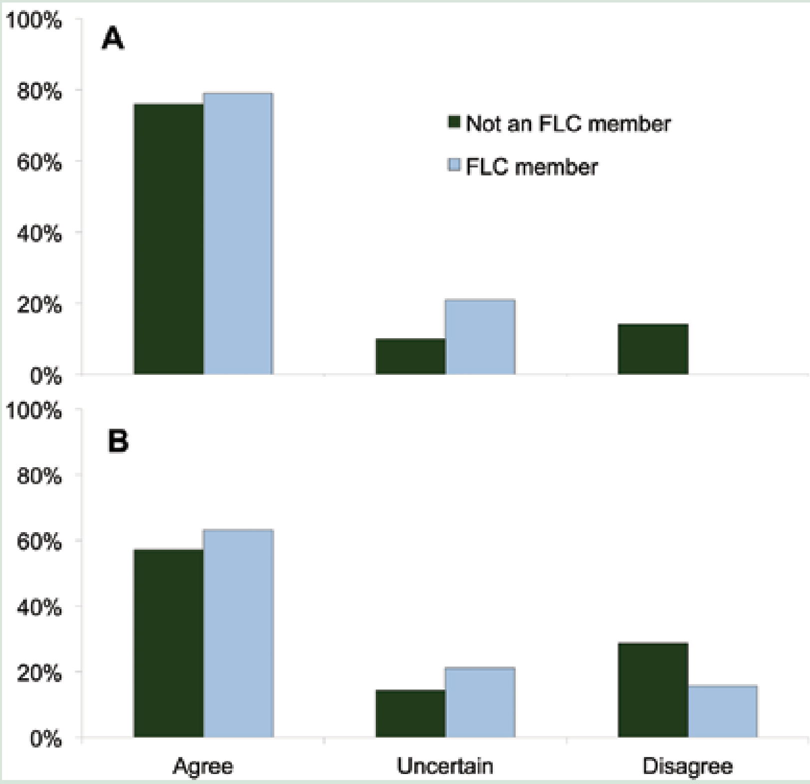


The faculty in the FLCs discussed, debated, and defined the learning goals for their courses, suggesting progress toward the second and third objectives. The survey showed that 94% of FLC participants agreed with the statement, "Over the past year, I have worked to clarify the learning goals in my courses." This represents a significant difference between FLC members and their faculty colleagues (Figure 4; $p = .009$ [FET]). In this respect, the FLC members are adopting backward design approaches—framing course content around learning goals (Handelsman, Miller, & Pfund, 2007).

Our survey did not assess progress toward the fourth objective. However, we report that faculty members have initiated creative approaches toward this end. Use of clicker response systems has increased: Only four faculty members used clickers in their introductory biology sessions prior to 2012, but as of spring 2012, eight used clickers and two more planned on using them the next year. Instructors of introductory biology courses have also used undergraduate teaching assistants to facilitate discussions during small-group, student-centered activities. Additionally, faculty members sought and received internal funding from our university to specifically create student-centered learning activities. This funding provided salary support for teaching assistants to create such activities as well as moneys to purchase technology to aid in the implementation of these activities. The graduate students gain knowledge in pedagogy, thereby aiding them in their own professional development. Faculty members have also received funds to invite seminar speakers whose research is in the area of biology education and to attend biology education workshops. All faculty that have sought such funds have been participants in the FLCs. The increased use of clickers and success competing for funding to support

FIGURE 5

Faculty responses to the statements: (A) "Other departmental faculty support efforts to improve college science teaching and learning" and (B) "My department is committed to reforming curricula and courses to enhance active learning and inquiry-based teaching." FLC = faculty learning community.



pedagogical innovations could mark the beginning stages of a cultural shift within the departments involved in the biology program at this university.

Collectively, the survey results and other positive developments at the department and college levels support the conclusion that FLCs have been a powerful driver for emergent change. One faculty member concurred: "I think the learning community is the biggest resource we have—it's pretty powerful." Moreover, 80% of faculty (both members and non-FLC members) surveyed felt that colleagues support efforts to improve teaching (Figure 5A), and a further 60% agreed with the statement, "My department is committed to reforming curricula and courses to enhance active learning and inquiry-based teaching" (Figure 5B).

Challenges still exist. For example, numerous faculty members have voiced concern over the lack of graduate teaching assistant support (teaching assistants are reserved primarily for labs). In addition, faculty are mixed in their belief that they will be recognized, evaluated, and rewarded for effective teaching (Figure 6), with the 48% being uncertain whether such recognition occurs. Part of this ambiguity is likely because departments have not yet developed strategies to assess, and thereby reward, faculty members for innovations resulting in improved instruction and learning. Our university, like many institutions, gives out teaching awards, but these tend to rely heavily on student evaluations, which can be informative but are also flawed, as there often is a positive correlation between the student's expected grade and his or her critique of the instructor (Carrell & West, 2010; Isley & Singh, 2010, Johnson, 2002; Salmons, 1993; but see also Centra, 2003). Furthermore, student evaluations are highly variable in their ability to assess the effectiveness of an instructor (Bedard & Kuhn, 2008; Marsh & Roche, 1997; Sproule, 2002). Although methodologies on evaluating faculty effectiveness are abundant (Berk, 2005), the feasibility of using many of them on a departmental scale, particularly in departments at universities that prioritize research, is low. One approach may be to formally document evidence of scholarly teaching that internal and external reviewers could use for evaluation.

Next steps

Our immediate next steps will focus on implementing and assessing Objective 4: assisting faculty in implementing and managing SCAL in large lectures. For example, we are expanding the use of undergraduate TAs to aide in the student-centered structure of class meeting. When students in the class are working in groups, the undergraduate TAs circulate in the classroom with the instructor to facilitate student discussions. This is being more widely implemented, and undergraduate TAs are willing to participate in exchange for course credit, making this potentially a sustainable mechanism for implementing change.

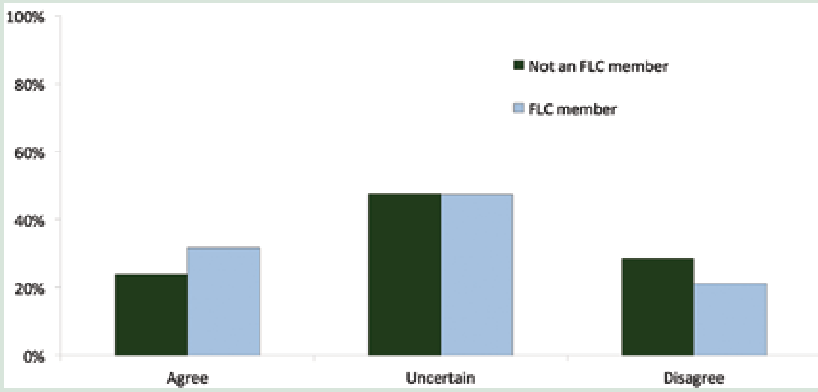
As of spring 2012, we have not formally surveyed students on their feelings regarding active, student-centered learning in the classroom. This work in ongoing. Anecdotally, students seem to appreciate active learning more if they can directly see how the activities assist them in test preparation, concurring with others' findings (e.g., Prince & Felder, 2007). Students resistant to student-centered learning could transfer to a more traditional lecture format or an online section, although as our project progresses, the availability of such sections will diminish. Students have limited options to take the courses elsewhere because transfer credit is not guaranteed.

In the longer term, we need to assess the effectiveness of implementing student-centered teaching approaches. The increased use of clickers in large classes is encouraging, but assessments are needed to determine which clicker questions are being used effectively to increase student engagement. Because instructor perception is not always accurate, a better approach would be to independently assess instructor use of student-centered pedagogy (Ebert-May et al., 2011; Fung & Chow, 2010). It is important that we also assess whether student success improves with increased implementation of student-centered activities. One approach will be through a comparison of student grades from classes before implementation of active learning to those after. Also, we will assess content learning gains using questions from biology concept inventories (Anderson, Fisher, & Norman, 2002; Garvin-Doxas & Klymkowsky, 2008; Shi et al., 2010; Smith, Wood, & Knight, 2008). These assessments will occur both within the introductory courses and in subsequent courses. As they progress through their degree program, students will be tracked and monitored to determine if the structure of the introductory biology courses helps them throughout their academic careers.

Last, we need to continue the conversations. Changing the culture of a department or a program is a long-term process—one that will continue long after our initial funding ends. For these new ideas to germinate and propagate, the incentives and motivations to change need to fit into the existing structure and system of the university (Henderson, Beech, & Finkelstein, 2011). Grant support is helpful to initiate change but not sufficient for maintenance of pedagogical change (Gess-Newsome, Southerland, Johnston, & Woodbury, 2003). We therefore need to develop sustainable models.

FIGURE 6

Faculty responses to the statement, "Departmental faculty are recognized, evaluated, and rewarded for effective teaching." FLC = faculty learning community.



Final note on using FLCs

Our experiences revealed that some FLCs were more successful than others. We found that FLCs with specific goals at the outset were more successful than those that began with poorly defined or few goals. For example, one semester an FLC focused on designing active learning activities for each primary topic covered in Biol 212. That FLC was highly successful, and as a result these practices were implemented. Although an organizer is necessary to manage the meeting logistics, we recommend having the participants of the FLC rather than the organizer decide on the goals, as such an approach increased the commitment and engagement of the participants in the FLC. Additionally, having one or two enthusiastic and motivated participants, in addition to the organizer, greatly helps maintain the momentum of the FLC. ■

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