A Faculty Development Model for Transforming a Department's Laboratory Curriculum With Course-Based Undergraduate Research Experiences

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Many studies illustrate the positive influences of undergraduate research experiences on student learning, attitudes, and retention in the sciences. At our institution, over 90% of the biology majors surveyed reported a desire to participate in undergraduate research, but only 3% per year have the opportunity to work in a traditional faculty-mentored setting. To address this discrepancy, the Department of Biological Sciences is redesigning 12 existing laboratory courses using the principal design elements of course-based undergraduate research experiences. The redesigned courses will span the entire curriculum and provide over 1,700 majors and premajors repeated experiences working on a real scientific problem—human impacts on the American River Ecosystem. We are using a multiyear Faculty Learning Community (FLC) to train and support faculty as they develop, implement, and peer review the research-based laboratory courses. In this article, we describe (a) our strategy for recruiting and engaging faculty to participate in the program, (b) the primary FLC activities with early evaluation data, and (c) lessons learned from the experience and plans for expanding the program across other disciplines and campuses.

Multiple scientific organizations and committees have called for institutions to teach science the way it is performed by professional scientists, with an emphasis on inquiry, autonomy, and discovery-based experiences (American Association for the Advancement of Science [AAAS], 2011; President's Council of Advisors on Science and Technology, 2012). One way for students to gain this training is through participation in undergraduate research experiences (UREs). A growing body of literature concludes that UREs lead to a variety of student benefits, including greater perseverance in science, technology, engineering, and mathematics (STEM) disciplines; more comprehensive content knowledge; and enhanced self-efficacy and critical thinking skills (Lopatto, 2007; Seymour, Hunter, Laursen, & DeAntoni, 2004). Although there is strong evidence behind recommendations that institutions offer more UREs, universal challenges related to faculty time, funding, and availability of space often limit the number of available positions (National Academies of Science, Engineering and Medicine, 2017). Furthermore, there are often inequities related to access to these opportunities (Bangera & Brownell, 2014). Many UREs are competitive internships that occur outside of normal class time or during the summer, when some students must seek employment. Additionally, the majority of students obtaining UREs are those that have demonstrated high academic achievement, that are aware of the benefits associated with the opportunities, and that possess some knowledge of the protocol for securing a research position. This is an important observation, as students who obtain research experience are more likely to be accepted into STEM graduate programs, which lead to academic careers and more influential positions in industry and government (Harvard University, 2013; Webb, 2007). Thus, by limiting the research opportunities at the undergraduate level to a select population, we impact the diversity of our STEM professorate and nonacademic workforce.

A proposed solution to some of the obstacles surrounding UREs is the course-based undergraduate research experience (CURE). CUREs integrate four elements of traditional research into one course: the use of science practices, collaboration, iteration, and novel discovery with broad relevance or importance (Auchincloss et al., 2014). Offering research in the required course curriculum allows a greater number and more diverse group of students to participate. Lower division students do not compete for internships with upper division students, students with financial and/or time constraints do not have to sacrifice employment or financial stability, and underrepresented minorities are reached with the same frequency as majority students. Laboratory costs are an important consideration in CURE design, but institutions can absorb these costs by eliminating materials used in "cookbook" labs or through student lab fees. As more studies on CUREs emerge, data suggest that these experiences afford many of the same benefits as research conducted in a faculty-sponsored lab or internship, including improvements in student processing skills, research competencies, and attitudes about science (Brownell, Kloser, Fukami, & Shavelson, 2012; Harrison, Dunbar, Ratmansky, Boyd, & Lopatto, 2011; Lopatto et al., 2008; Shortlidge & Brownell, 2016).

CUREs address the national calls for science pedagogical reform, and data support a range of student benefits; yet less is known about the impacts on faculty attempting to design and implement research-based laboratories. Several national consortiums support faculty in these efforts, but they generally encourage the adoption of specific research projects, such as the SEA-PHAGES program from the Howard Hughes Medical Institute (http://seaphages.org/) or the *Drosophila* genome project sponsored by the Genomics Education Partnership (see http://gep.wustl.edu; Lopatto et al., 2014). For faculty developing their own CUREs, a recent study found that faculty enjoyed the teaching experience more; appreciated and benefited from including their own research interests in their courses; and in some cases, received benefits related to tenure or promotion, publication, or external funding (Shortlidge, Bangera, & Brownell, 2016). This study also identified a number of challenges, including financial constraints, the need to invest significant time in the planning and implementation of CUREs, and the necessity for setting student expectations and managing student resistance. Many of the reported challenges reflect those of faculty mentoring URE students, yet the larger number of students in most CUREs presents a unique problem for faculty adopting a research-based curriculum.

Department-wide curricular reform effort

In addition to the call for a more research-infused curriculum, *Vision and Change in Undergraduate Biology Education: A Call to Action* (AAAS, 2011) called for biology faculty to develop coordinated plans to improve instruction. The literature on pedagogical and institutional change contends that overarching curricular reform can be difficult, and many institutions have encountered resistance from faculty faced with a lack of time, training, and incentives (Brownell & Tanner, 2012; Dancy & Henderson, 2010). Brownell and Tanner (2012) also suggested that resistance may stem from tension between instructors' professional identities as scientists and teachers. Others have shown that some faculty ignore empirical evidence in favor of anecdotal experiences when making decisions about their teaching and that dissatisfaction with their teaching alone is not sufficient to instigate change (Andrews & Lemons, 2015). Multiple studies highlight faculty development programs that fail to motivate the adoption or continued use of the instructional strategies they promote (Derting et al., 2016; Ebert-May et al., 2011; Henderson, Beach, & Finkelstein, 2011). Overcoming these challenges is intensified when the curricular reform requires participation of a large group of faculty, such as those belonging to a subdiscipline or academic department.

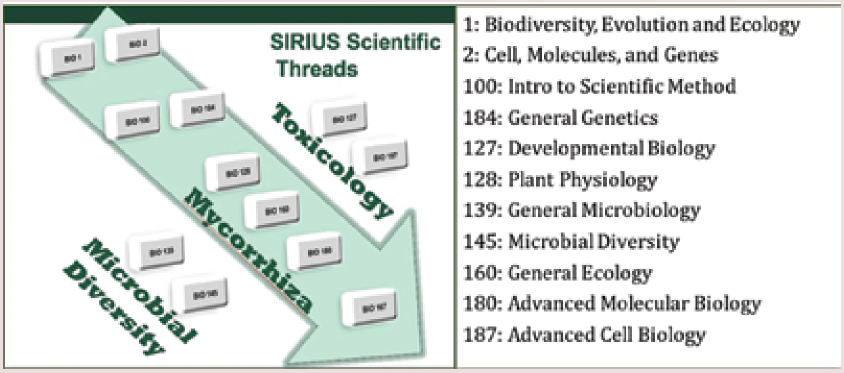
In the Department of Biological Sciences at our institution, we are addressing the calls for more authentic scientific experiences for students and coordinated curricular reform efforts by faculty through the Sustainable Interdisciplinary Research to Inspire Undergraduate Success (SIRIUS) project. This National Science Foundation–funded project incorporates research experiences, based on the critical elements of CUREs, into 12 existing laboratory courses coordinated around three scientific threads that address a common and relevant problem for our campus and community—the human impacts on the American River Ecosystem. The collective effort of our faculty is unique in both design and scale, as it delivers an integrated curriculum to all of our approximately 1,700 biology majors, beginning with the introductory biology lab series and continuing through advanced capstone courses (Figure 1). We are using a 5-year Faculty Learning Community (FLC) to support faculty teams as they learn to design, implement, and assess their CUREs. Our FLC activities are influenced by the work of Henderson and colleagues as we seek to develop our community around two effective approaches to promote change: developing a shared vision and reflective teaching practices (Henderson et al., 2011). According to Henderson and colleagues, the role of the change agent in establishing a shared vision is "to catalyze or empower individuals to come together and work toward collectively envisioned change" (p. 963). Our shared vision emerged from regular meetings with individuals, teams, and the department over the course of several years as we collectively examined our problems and identified strategies to address them. To promote reflective teaching, the change agent facilitates and supports faculty as they "use their own knowledge/experience/skill to improve their instructional practices" (Henderson et al., 2011, p. 961). Our FLC provided a supportive venue for faculty teams to both acquire new knowledge and skills and apply them to curriculum reform. In this article, we present our strategy for engaging faculty in this department-wide effort, recruiting them to participate in the FLC and supporting them as they collaboratively design and implement the new curriculum. We also present early evidence to support the success of our program and discuss lessons learned and future directions. As we are only 3 years into a 5-year program, most of our faculty and student outcome data will be reported at the conclusion of the project.

Faculty engagement and recruitment

Faculty interest in teaching research-based labs was initially revealed through informal department meetings to discuss the *Vision and Change* report (AAAS, 2011). Not all faculty were comfortable adopting some of the pedagogical recommendations; however, there was unanimous interest in revising several laboratory courses to include more authentic scientific practices. At our primarily undergraduate institution, teaching is prioritized over research, and at the time, there

FIGURE 1

The 12 SIRIUS courses designed along three scientific threads.



was a 200:1 student-to-faculty ratio, which led to the assumption that only a small percentage of our students were gaining experience in faculty research programs. To test this assumption and determine the actual number of students participating in UREs in our department, we developed and administered surveys to our 18 full-time faculty members and 295 upper division students. Our data revealed that 67% of our faculty was mentoring an average of three students/year, which accounted for less than 3% of our biology majors. In contrast, 91% of students reported an interest in performing research. There were various barriers to participation by faculty and students, but lack of time presented the greatest challenge for both (Table 1).

To determine whether students were receiving inquiry-based experiences through the department's curriculum, we evaluated eight individual laboratory exercises from three courses (representing introductory, intermediate, and capstone) using a rubric from Bruck, Lowery Bretz, and Towns, 2008. Although these exercises represented only a portion of our laboratory curriculum, our findings revealed very low levels of inquiry across the courses. Results from these programmatic assessments demonstrated a strong need to improve the learning experiences for our students and provided us with convincing data to garner support from faculty and administration.

Next, we expanded discussions with faculty to strengthen commitments and define plans for individual course redesigns. We began one-on-one and small-group conversations to gauge interest in coordinating research efforts around a common theme focused on the American River Ecosystem. Flowing through our campus, the American River is an urban, agricultural, rural, riparian habitat that is listed as "Impaired" by the Federal Clean Water Act of 1972; thus, it provides a convenient, relevant, and important natural resource for our faculty and students to study. Furthermore, after several years of drought, our theme was

TABLE 1

Most common barriers to participation in undergraduate research programs for faculty and students.

Faculty barriers	% Responding	Student barriers	% Responding
Lack of time	55%	Lack of time	50%
Lack of funding	44%	Lack of opportunity	45%
Insufficient space	11%	Lack of awareness	14%
		No interest	2%

well aligned with the programmatic and research priorities emerging on our campus and at the state level. We identified 12 courses that were appropriate for the project and three scientific themes of interest to our faculty—the diversity of bacterial populations, the ecological interactions of mycorrhizal fungi and plants, and the environmental toxicology from human inputs (Figure 1). Some faculty identified projects related to their own research; however, others proposed novel projects of interest to them or that were well-aligned with their course's existing structure and learning outcomes. The fact that the ideas generated by faculty could be grouped into threads provided an opportunity to link the curriculum in courses addressing similar themes (see Appendix 1, available at https://www.nsta.org/college/connections.aspx for examples of linked course within the three course threads). This led to the development of working groups of faculty and staff that could use a backward design strategy to integrate curriculum across courses ranging from introductory to advanced. This also allowed for the inclusion of courses that would not serve as standalone CUREs, but would contribute to a series of courses that together would constitute a CURE. This was important, as some faculty were reticent to redesign their entire 16-week laboratory course around the American River theme, although most were willing to dedicate a series of labs or a module.

The dedication of fewer class sessions to the SIRIUS theme allowed for greater faculty participation; however, we were concerned that relatively short research projects would fail to have a significant impact on students. To explore this, we designed a 4-week research module (Model Lab) that replaced existing curriculum in an upper division Developmental Biology course. In this module, students studied the population dynamics of *Caenorhabditis elegans* under normal conditions and when exposed to toxins found in surface water or soil, including that of the American River. We assessed the impact of the new curriculum on student knowledge, skills, and attitudes using pre/post surveys, lab reports with attitudinal questions, an exam essay coded for the presence of CURE design elements, and focus groups (two with Model Lab and two with URE students).

TABLE 2

Daily schedule for the SIRIUS Summer Institute.

Time / Period	Inquiry Monday	Science Tuesday	Assessment Wednesday	Technology Thursday	Alignment Friday
8:30–9:00	Breakfast Networking	Breakfast Networking	Breakfast Networking	Breakfast Networking	Breakfast Networking
9:00–10:00 10:00–11:00 11:00–12:00	- Introductions - Overview of SIRIUS Project - Intro to UREs, CUREs and inquiry-based learning - Evaluation of inquiry in the classroom activity - Guest speakers from UC Berkeley	- Discussion of shared materials for SIRIUS courses - Course teams work to find literature and mine public data appropriate for the SIRIUS science labs	- Overview of literature: Assessing CUREs - Human Subjects and IRB (guest) - Assessment across SIRIUS courses - Plans for using CAT Instrument (for critical thinking)	- Technology in the classroom: Presentations on e-lab book and e-portfolio - Overview of Keck-funded mobile research instruments - Rotating hands-on technology training	- Environmental Health and Safety (guest) - Responsible Conduct of Research (guest) - Groups report out status of CURE development
12:00–1:00	Lunch Discussions	Lunch Discussions	Lunch Discussions	Lunch Discussions	Lunch Discussions
1:00–2:00 2:00–3:00 3:00–4:00	- Building and assessing the model CURE (BIO127) - Break out into course teams to work on CUREs - Team presentations	- Discuss scientific quality and integrity - Reconvene: discuss overall scientific strategy for SIRIUS	- Break out into course teams to plan for course-specific assessments - Reconvene: discuss overall assessment strategy for SIRIUS	- Break out into lab groups to discuss integration of technologies into course designs - Reconvene: discuss overall technology strategy for SIRIUS	- Open discussion of alignment of SIRIUS courses and and future directions

Note: CURE = course-based undergraduate research experience; SIRIUS = Sustainable Interdisciplinary Research to Inspire Undergraduate Success; URE = course-based undergraduate research experience; IRB = Institutional Review Board; CAT = Critical Thinking Assessment Test.

Focus-group data provided some of the most compelling evidence for the impacts of the 4-week module. Both Model Lab and URE students revealed a sense of project ownership and recognized the importance of troubleshooting, collaboration, and literature reviews. Furthermore, students from the Model Lab recognized the presence of scientific practices (in 85% of the essays), collaboration (68%), relevance and discovery (50%), and iteration (45%) in their laboratory work. These results demonstrated that even a 4-week research module could have a positive impact on students and convinced us that the inclusion of courses without a semester-long project would enhance the learning experiences for students.

We used curricular ideas generated by our faculty and data from URE participation surveys and the Model Lab evaluation as the basis for the SIRIUS proposal submitted to the Improving Undergraduate STEM Education Program at the National Science Foundation. The SIRIUS project was funded for 5 years to support the redesign, implementation, and evaluation of the 12 laboratory courses. The grant supports faculty through an FLC, as these models have shown particular promise for driving faculty and institutional change and effectively supporting science faculty as they adopt new evidence-based teaching strategies (Elliott et al., 2016; Sirum & Madigan, 2010). Faculty compensation for participating in the SIRIUS FLC for up to 4 years made up approximately 8% of the budget, with additional funding allocated to pay students and staff for their participation in the FLC and for student assistance with data collection and analysis. Funds were allocated for reagent and small instrument purchases to help faculty with initial curriculum designs; however, all course expenditures are covered by operating expenses and lab fees after the first or second implementations.

SIRIUS FLC: Activities and impacts

The SIRIUS FLC began with an intensive 1-week Summer Institute (SI) in June 2015 that addressed the

TABLE 3

Summary of data from End-of-Summer Institute Survey.

Select items on End-of-Summer Institute Survey	Percentage agreement
It was useful to work in teams of faculty, students and staff.	100%
It was useful to work in teams across courses.	92%
I/we made substantial progress on developing CURE curriculum.	67%
I/we need to work more on assessment strategies.	33%
I/we need to work more on specific lab protocols, logistics, or written manuals.	50%
I feel prepared to teach new curriculum according to the timeline.	75%
I/we could use more support with collaboration and communication within and across courses.	50%

FIGURE 2

Perceived value of Summer Institute activities.

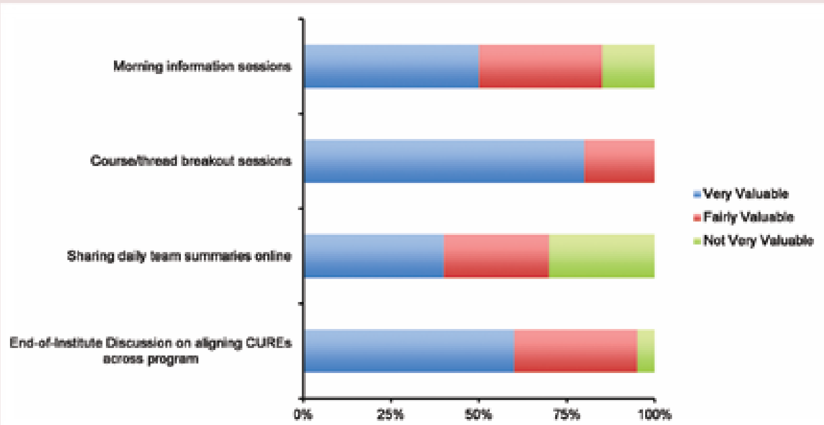


TABLE 4

Breakdown of faculty motivators reported when they were asked "What initially convinced you or motivated you to become involved in the SIRIUS project?" based on their stage of career.

	Student benefits	Faculty benefits	Curricular benefits	Respect for PIs
Assistant professors	60%	22%	38%	0%
Associate professors	20%	11%	13%	50%
Full professors	20%	67%	50%	50%

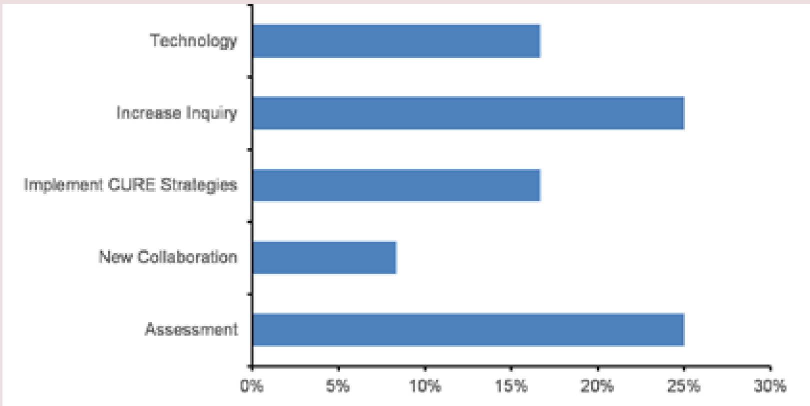
Note: Responses could fall into more than one category. SIRIUS = Sustainable Interdisciplinary Research to Inspire Undergraduate Success; PIs = Principal Investigators.

following goals: (a) provide relevant background and training for creating CUREs; (b) collect and share resources to support the science underlying the CUREs; (c) provide relevant background and training for the development of CURE assessments; (d) provide an overview of web-based tools/resources for use in the CUREs; (e) provide training related to scientific instrumentation for use in the CUREs; and (f) create a productive and collaborative environment for developing the CUREs (Table 2). The SIRIUS Principal Investigators (PIs) and guest speakers provided the training related to the goals above. Safety, responsible conduct in research, and human subject's guidelines were also addressed by experts at our institution. Mornings were dedicated to informational lectures and activities, guided largely by the concepts, framework, and recommendations established in Auchincloss and colleagues' (2014) meeting report on the assessment of CUREs. Afternoons provided faculty with time to work on their curriculum with their course and thread teams. At the end of each day, the whole group reconvened for a final discussion, and participants completed individual reflections that prompted them to consider (a) which concepts or strategies from the day they could readily apply in their curriculum design and teaching and (b) which topics that they wanted to explore further or for which they had questions. These reflections also served as formative assessments for the SI coordinators. Additional details linking SI activities to the faculty development goals are in Appendix 2 (available at https://www.nsta.org/college/connections.aspx).

An End-of-Summer Institute Survey showed high levels of satisfaction with the week's activities (Table 3). All responding participants reported that they felt the SI goals were met and that the SI achieved a productive and collaborative environment for creating CUREs. Survey respondents reported the most valuable SI activities were the daily breakout sessions for course/thread teams to apply their learning and design CURE curricula along with the discussion on aligning CUREs across the entire biology program (Figure 2).

FIGURE 3

Breakdown of how biology faculty members are using knowledge gained from the SIRIUS Summer Institute in other areas of their scholarship. Data from 33% of faculty who reported using new knowledge.



Faculty interviews conducted three months after the SI provided additional information about motivation to join the FLC and learning gains resulting from the SI. Interview responses revealed four primary motivators for participation, including (a) the benefits the new curriculum would have on students (21% of responses); (b) the benefits participation would have on faculty, both personally and professionally (37.5% of responses); (c) the benefits the project would have on the cohesiveness of the department's curricula and the department itself (33% of responses), and (d) respect for the PIs of the SIRIUS project (8% of responses). Table 4 illustrates how these motivators differed for faculty in different stages of career, which is important to consider when recruiting faculty from across an entire department.

Three fourths of interviewees indicated that the collaborative environment was one of the most valuable aspects of the SI, and 25% specifically mentioned the benefits of learning about inquiry and assessment strategies. Thirty-three percent of interviewees indicated that they were applying newly acquired knowledge or strategies to activities unrelated to the SIRIUS project, with the majority using alternative assessment strategies and attempting to increase inquiry in their non-CURE courses (Figure 3).

For three summers following the SI (2016–2018), the FLC involved a 2-day Peer Evaluation Workshop (PEW), held over two 8-hour days at the end of May. Peer Evaluation Workshop 1 (PEW1), held in May 2016, included time for each course team to present their new curriculum and for the courses implemented in the 2015–2016 academic year to discuss successes, challenges, and lessons learned. Time was allocated for teams to work together and for all FLC members to provide feedback and ideas for improving the labs. Time was further devoted to reviewing the assessment tools that were being used to collect baseline data (pre-CURE implementation) and student outcome data (for implemented labs).

Peer Evaluation Workshop 2 (PEW2), held in May 2017, provided time for each course team to present progress, challenges, and assessment data. In addition, the PIs ran workshops on writing student learning outcomes and developing a longitudinal skills profile, which documents the technical (e.g., Polymerase Chain Reaction, microscopy) and academic (e.g., reading the literature, communicating results, peer reviewing) skills being taught in each course. The products of these activities are being used to improve alignment and scaffolding across the entire SIRIUS curriculum. As a reflective activity, workshop participants completed the Laboratory Course Assessment Survey (LCAS; Corwin et al., 2015), modified for instructors, to gauge the degree to which collaboration, iteration, and discovery with broad relevance (three critical design elements of CUREs) were successfully integrated into the new curriculum. LCAS data collected from students over two semesters in the newly designed Introductory Biology labs are providing early evidence that stu-

TABLE 5

Summary of Laboratory Course Assessment Survey (LCAS) responses from BIO1 students in the spring 2016 and spring 2017 semesters. Students reported how often or to what extent they agreed with the statements under each of the three constructs of the survey.

			Spring 2016	Spring 2017
Item	**Construct**	**I was encouraged to…**	**% Weekly/ Every Other Week**	**% Weekly/ Every Other Week**
1	Collaboration	discuss elements of my investigation with classmates or instructors.	81%	67%
2		reflect on what I was learning.	86%	92%
3		contribute my ideas and suggestions during class discussions.	78%	89%
4		help other students collect or analyze data.	76%	87%
5		provide constructive criticism to classmates and challenge each other's interpretations.	46%	73%
6		share the problems I encountered during my investigation and seek input on how to address them.	70%	83%
Item	**Construct**	**I was expected to…**	**% Agree**	**% Strongly Agree/Agree**
7	Discover/Relevance	generate novel results that are unknown to the instructor and that could be of interest to the broader scientific community or others outside of class.	42%	40%
8		conduct an investigation to find something previously unknown to myself, other students, and the instructor.	55%	73%
9		formulate my own research questions or hypothesis to guide an investigation.	76%	83%
10		develop new arguments based on data.	67%	80%
11		explain how my work has resulted in new scientific knowledge.	61%	84%
12	Iteration	revise or repeat work to account for errors or fix problems.	49%	82%
Item		**I had time to…**	**% Agree**	**% Strongly Agree/Agree**
13		change the methods of the investigation if it was not unfolding as predicted.	47%	67%
14		share and compare data with other students.	77%	80%
15		collect and analyze additional data to address new questions or further test hypotheses that arose during the investigation.	55%	76%
16		revise or repeat analyses based on feedback.	54%	80%
17		revise drafts of papers or presentations about my investigation based on feedback.	61%	79%

dents recognize their involvement in collaborative, iterative, and relevant research (Tables 5 and 6). These data are also providing valuable insight into specific elements of the curriculum that should be targeted for further revision.

Data from surveys conducted at the end of PEW1 and PEW2 indicated that the goals of the workshops were met, as faculty felt better informed and obtained valuable input from colleagues that they could use to improve their curricula. The PIs are using survey data regarding faculty member's greatest needs to plan for academic year meetings and the final PEW in summer 2018 (see Appendices 3–5 available at https://www.nsta.org/college/connections.aspx).

Lessons learned and future directions

After 3 years of the project, we have implemented 8 of 12 redesigned laboratories, with the final four scheduled for implementation in the 2017–2018 academic year. Our redesigned courses have already impacted over 3,800 students, and faculty participation has grown since

TABLE 6

Summary of Laboratory Course Assessment Survey responses from BIO2 students in the spring 2016 and spring 2017 semesters. Students reported how often or to what extent they agreed with the statements under each of the three constructs of the survey.

	Spring 2016	Spring 2017		
Item	**Construct**	**I was encouraged to…**	**% Weekly/ Every Other Week**	**% Weekly/ Every Other Week**
1	Collaboration	discuss elements of my investigation with classmates or instructors.	87%	91%
2		reflect on what I was learning.	83%	92%
3		contribute my ideas and suggestions during class discussions.	78%	88%
4		help other students collect or analyze data.	77%	86%
5		provide constructive criticism to classmates and challenge each other's interpretations.	54%	69%
6		share the problems I encountered during my investigation and seek input on how to address them.	82%	85%
Item	**Construct**	**I was expected to…**	**% Agree**	**% Strongly Agree/Agree**
7	Discover/Relevance	generate novel results that are unknown to the instructor and that could be of interest to the broader scientific community or others outside of class.	53%	66%
8		conduct an investigation to find something previously unknown to myself, other students, and the instructor.	61%	73%
9		formulate my own research questions or hypothesis to guide an investigation.	73%	85%
10		develop new arguments based on data.	57%	80%
11		explain how my work has resulted in new scientific knowledge.	63%	84%
12	Iteration	revise or repeat work to account for errors or fix problems.	77%	81%
Item		**I had time to…**	**% Agree**	**% Strongly Agree/Agree**
13		change the methods of the investigation if it was not unfolding as predicted.	60%	68%
14		share and compare data with other students.	57%	80%
15		collect and analyze additional data to address new questions or further test hypotheses that arose during the investigation.	49%	76%
16		revise or repeat analyses based on feedback.	63%	80%
17		revise drafts of papers or presentations about my investigation based on feedback.	72%	79%

TABLE 7

Number and affiliation of participants in summer Faculty Learning Community (FLC) activities.

SI participant groups	Summer Institute (2015)	PEW1 (2016)	PEW2 (2017)
Biology faculty	13	17	15
Other STEM faculty	4	5	6
Biology staff	1	3	2
Graduate teaching assistants	1	0	1
Undergraduates	10	0	0
Administration	1	1	3
Total	30	26	27

Note: SI = Summer Institute; STEM = science, technology, engineering, and mathematics; PEW = Peer Evaluation Workshop.

the beginning of the grant (Table 7).

Although we have collected some data on faculty motivation (Table 4), we believe several additional factors were influential in initially attracting faculty and encouraging their long-term engagement. In brief, we built a shared vision and established a common goal early in the process, and we continued to cultivate a community of practice with three primary activities. First, we encouraged faculty to take ownership and guide the development of the scientific threads and research questions aligned with their interests and expertise. We also collected and shared data demonstrating a need and showed proof of concept with the design and evaluation of our Model Lab. Last, once the FLC was established, we maintained continuity with course and thread teams meeting during the academic year and at least one meeting of the whole group occurring each semester. The whole-group academic-year meetings occurred during time blocks reserved for faculty and committee meetings and were designed to provide updates on implementation and student learning outcomes. They were well attended and open to the entire department; therefore, they also served as a means of recruiting additional faculty. The course-based group meetings generally occurred during regularly scheduled lab planning meetings and were focused on building and troubleshooting the specific curriculum. We have also allowed for flexibility in the schedule and design, as some CUREs have taken longer to develop than others, and several have needed to make major changes to research questions and protocols, even after implementation. The time to reflect and work with other faculty during the FLC activities has been important in helping to resolve most of the issues that individual courses have faced. In an early oversight, we failed to train instructors that were not part of the FLC, most of whom represented part-time faculty or GTAs teaching lower division labs. We are currently developing a strategy to train non-FLC members in a presemester workshop on CUREs and the SIRIUS project.

Plans are already underway to expand the project to other STEM disciplines on our campus, as well as STEM disciplines at four of our feeder community colleges. Faculty from the Departments of Geology, Environmental Studies, and Chemistry have been active in our FLC, and six redesigned labs (two per discipline) are scheduled for implementation in the upcoming academic year. Working with other STEM disciplines affords the opportunity to address research questions from truly interdisciplinary perspectives, and engaging our community college colleagues will provide a smooth transition for the large number of transfer students that enter our majors each year. ■

Acknowledgments

The SIRIUS Program is supported by the National Science Foundation (DUE-1432299), W. M. Keck Foundation, California State University Program for Education and Research in Biotechnology (CSUPERB), and University Enterprises, Inc. at Sacramento State. We also are grateful to the many faculty members and students at Sacramento State who participated in the training and data collection activities described in this article. Last, we thank the anonymous reviewers for specific and thoughtful feedback.

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