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Abstract
Many undergraduate institutions are reforming their courses to increase student engagement. A critical challenge in these efforts is to engage the academic community beyond the instructors in the process of change. At our university, we embraced this challenge by creating a volunteer community of faculty, postdocs, graduate students, and undergraduates to design the discussion curricula for a new introductory biology sequence. We report on this process of curriculum development using a case study approach and describe how the community created the new curriculum and how they perceived the outcomes of the process. Our findings indicate that this curriculum design approach was embraced by the community as a valuable process and produced a set of courses with a satisfying and shared vision for student learning. We compare our community curriculum design process to those others have used, and conclude that this process is widely applicable across disciplines and institutions to design new curricula.

Keywords
curriculum, introductory biology, community, curriculum reform

Cover Page Footnote
We would like to thank the curriculum community members who volunteered to help redesign the introductory biology discussion curricula and the NSF for funding the project (DUE 1245215).

Taking a Community Approach to Curriculum Change

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Many undergraduate institutions are reforming their courses to increase student engagement. A critical challenge in these efforts is to engage the academic community beyond the instructors in the process of change. At our university, we embraced this challenge by creating a volunteer community of faculty, postdocs, graduate students, and undergraduates to design the discussion curricula for a new introductory biology sequence. We report on this process of curriculum development using a case study approach and describe how the community created the new curriculum and how they perceived the outcomes of the process. Our findings indicate that this curriculum design approach was embraced by the community as a valuable process and produced a set of courses with a satisfying and shared vision for student learning. We compare our community curriculum design process to those others have used, and conclude that this process is widely applicable across disciplines and institutions to design new curricula.

INTRODUCTION

Faculty across the United States have been challenged to engage students more meaningfully in their own education. In the Biological Sciences disciplines, these calls have focused on re-envisioning introductory biology courses to maximize student learning and retention of students in the discipline (AAAS, 2011; PCAST, 2012). These calls for new approaches in science teaching arose from negative perceptions of science courses articulated by students leaving the science major (Seymour and Hewitt, 1997) and were magnified by recent studies showing that course pedagogy profoundly impacts student learning and achievement (Freeman et al., 2014; Haak et al., 2011). In the pivotal *Vision and Change in Undergraduate Biology Education* report (AAAS, 2011), experts from across the country called for change in biology education along four critical dimensions: 1) taking a more conceptual approach to content and more fully integrating process skills into introductory courses, 2) focusing instructional practices on techniques that actively engage students in their own learning, 3) promoting a campus commitment to change in teaching and learning, and 4) engaging the entire academic community in the process of change.

These comprehensive calls for reform will require an academic community mobilized for action, in a context that is often unfamiliar with large-scale curriculum reform efforts. Faculty, although charged with designing the curriculum as a whole, are often more concerned with their own courses than the collective courses of the department (Briggs, 2007). Significantly, faculty may rely on a very small group of confidants when it comes to discussing teaching, and those conversations are often hidden from view in academia (Roxa & Martensson, 2009). The formation of explicit communities of practice has been found to take these hidden discussions and broaden and expose them as a regular part of practice within a department (Laksov, Mann, & Dahlgren, 2017). These are often framed as faculty learning communities and are based on the idea of a community of practice (Lave & Wenger, 1991), where faculty within a similar domain and with a mutual commitment interact to make meaning of their experience. Faculty learning communities can focus on any shared experience, and can include discussions of teaching and learning, research, or curriculum creation.

Henderson, Finkelstein, & Beach (2010) and Henderson, Beach, & Finkelstein (2011) reviewed the literature on academic change and categorized reform efforts into four approaches: creating and disseminating curriculum, developing reflective teachers, developing policy, and developing shared vision. Although evidence for successful change is often lacking in many studies, they suggested that top-down strategies do not work well in academia. What does seem to work are long-term strategies situated within and honoring the context of the academic system (Henderson, Beach, & Finkelstein, 2011). Given the literature on communities of practice and faculty learning communities, we suggest that this communal approach may be the best grassroots strategy to engage a department in a curriculum reform process.

Communities of practice may be particularly important when creating consensus learning outcomes for introductory courses. For example, curriculum change to promote student competency (process) skills may be a particular challenge to reach agreement about, given how rare explicit learning outcomes of this nature are in typical introductory science courses (Coil et al., 2010) and how important these outcomes may be to multiple courses beyond the introductory level. Changes such as these require faculty discussions about what process skills students should learn in order to reach consensus about and integrate these expectations into courses. One outcome of these discussions is that departments who go through this process have been shown to focus more on student learning in their curriculum reform efforts (Briggs, 2007; Duncan et al. 2006). Others have also suggested that communities of faculty engaging in meaningful discussion about the intended learning outcomes of new curricula should result in more transparency and attainment of learning outcomes by students (Allen & Tanner, 2006; Wiggins & McTighe, 1998).

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The nationwide reforms to introductory biology called for in *Vision and Change* propose engaging as much of the academic community as possible to foster a unified vision of reform as well as a culture of institutional change. In considering the academic community involved in introductory courses, the members who need to have input about the learning outcomes go beyond instructional faculty to also include graduate student instructors of introductory labs and discussions (Sundberg, Armstrong, & Wischusen, 2005) and the undergraduate students who take these courses. Engaging graduate students in curriculum reform is particularly important because many of them will design and implement courses when they move into future faculty roles (Brownell & Tanner, 2012; Sauermann & Roach, 2012). Bernstein & Greenhoot (2014) reported on a project that paired faculty with graduate student fellows and specialists across campus to make curricular changes to courses. The graduate students made critical contributions during the design phase of the courses and gained skills that made them more effective in their roles as teaching assistants. Also important are postdoctoral scholars, who are often not directly engaged in instruction yet may be seeking instructional positions that require an understanding of modern teaching and learning pedagogies in undergraduate contexts. Thus, a complete community of practice for introductory curriculum reform should include faculty, postdocs, graduate students, and undergraduate students sharing ideas about the design of the curriculum.

Cook-Sather, Bovill, & Felten (2014) called for faculty to explicitly engage students as partners when making curricular or pedagogical decisions. They argue that faculty-student partnerships that are grounded in the principles of respect, reciprocity, and responsibility have the potential to create powerful outcomes, such as increased student engagement in the learning process and transformations in how faculty think about teaching and learning. Faculty have also enlisted undergraduate students as partners in curriculum design, where the students have made significant contributions to the design of new courses or new activities for existing courses (Bovill, Morss, & Bulley, 2009; Woolmer et al., 2016). These are often powerful and transformative experiences for the students and faculty involved.

At our institution (a large research university), we embraced the challenge of creating new curricula consistent with the *Vision and Change* recommendations by using a community of participants that represented the broad academic context in which the courses were situated. In addition to faculty and graduate students, we also invited undergraduates and postdoctoral scholars into curriculum reform communities for the purposes of creating new graduate teaching assistant (TA)-led small group discussions associated with newly-revised introductory courses. In this article, we report on the context and community process of curriculum development by using a qualitative case study approach (Yin, 1992) to describe how the community created the new curriculum and how they perceived the outcomes of the process. Our findings indicate that this curriculum design approach was embraced by the community as a valuable process and produced a set of courses with a satisfying and shared vision for student learning in introductory biology.

METHOD

This case study focuses on the community of people who participated in the introductory biology curriculum design process at our institution during the 2013-2014 academic school year. Our investigation can be considered an instrumental case study (Stake, 1995) since we were interested broadly in a community-driven approach to curriculum design and chose to focus on this particular case as an example of that method. Although case studies are inherently specific, we aimed to gather data in a way that would allow us to make some generalizations about the effectiveness of a community-based approach to curriculum design. We employed a triangulation strategy for data collection, using surveys of community members and artifact collection, to provide a more thorough description of the curriculum design process and its outcomes.

Context of the Reform

Our institution offers bachelor's degrees in Biological Sciences, with students choosing to concentrate in one of three sub-disciplines: 1) Biochemistry, and Cellular and Molecular Biology, 2) Ecology and Evolutionary Biology, and 3) Microbiology. Prior to the curriculum reform, students majoring in Biological Sciences were required to take a two-course introductory biology course sequence before moving on to courses within their concentration. The two courses that made up the introductory sequence, Biodiversity and Organization and Function of the Cell, were the focus of the curriculum reform.

Prior to the reform, each course had a traditional structure of 3 hours of large lecture and 3 hours of lab every week (4 credit hours), but there were no small-group discussion sessions. Three or four sections of each course were offered per semester, each with 170-225 students in one large lecture. The course reform strategy was to use the recommendations of *Vision and Change* as a guide for the concepts, competencies, and teaching strategies used in each course. To start the reform, the lab was separated from the lecture courses to create a single-semester 2-credit hour course (lab and discussion) titled "Skills of Biological Investigation." The two lecture courses were retitled "Organismal and Ecological Biology" (henceforth, OEB) and "Cellular and Molecular Biology" (CMB) and common learning objectives aligned with the *Vision and Change* report were approved for the lecture portion of both courses. Weekly, hour-long, TA-led discussions were added to each lecture course to promote student understanding of the process of science as enacted by scientists. The community approach described in this article was used to create the curriculum for the new lab discussion, OEB discussion, and CMB discussion. This article focuses solely on the process of creating the OEB and CMB discussion curricula as examples of this method.

The curriculum reform project was funded by a National Science Foundation (NSF) TUES grant (DUE 1245215; PI Schussler). The majority of the grant funding provided support for a graduate research assistant (GRA; Co-author Auerbach) to coordinate the curriculum communities and aid in data collection for the project. There were no other expenses or costs associated with running the communities.

Curriculum Design Process

In late summer 2013, volunteer community members were recruited via e-mails to departmental and program graduate coordinators, the Division of Biology listserv, and the undergraduate lab assistant program. Faculty teaching the reformed introductory courses were especially encouraged to participate, but there was no monetary incentive for them or any other volunteer. Notably, none of the participants were told by a mentor or supervisor that they needed to participate. Undergraduate and graduate students were offered 1 credit of independent study course credit for their participation. The first week of classes, an organizational meeting with potential participants was held to explain the project and gauge interest. This process yielded a group of 25 participants (8 undergraduates, 9 graduate students, 3 post-docs, and 5 faculty). All faculty involved were non-tenure track (2) or mid-career, tenured faculty (3); four taught in the introductory sequence and three had some pedagogical training / interest. This larger group was then broken into smaller communities to focus on a particular course (OEB or CMB) based on their preference. Each community had at least one faculty member, graduate student, and undergraduate student (Figure 1). Since membership in the communities was distinct (no single person belonged to both communities), each community can be thought of as a "sub-case" in our case study research design.

The curriculum communities were charged with broad goals of creating a vision for each discussion section in the fall and then planning individual discussion classes in the spring. The discussion curricula were meant to be conceptually-related, but not explicitly linked, to weekly large lectures, removing potential constraints of trying to coordinate with variable faculty lecture schedules. Departments had previously voted to approve the new curriculum structure, but the exact content and details of the discussion sessions were left up to the project PI. Each community was instructed to design discussions that would help students read about and understand current scientific research articles as the overall foci of each discussion, but few restrictions or specifics about learning outcomes were given to allow the groups the freedom to create what they thought was most valuable. As the communities started their work, the PI and GRA answered any logistical questions that arose and provided guidance as needed. Although there were faculty members in each group, the groups were explicitly told that there were no "leaders" and every member had an equal voice. The communities met for one hour every two weeks to plan the curriculum and the agenda was set entirely by the group. At every meeting one member recorded meeting notes, and the GRA posted these notes and other curriculum resources on a community course management website viewable by all curriculum groups.

Over two semesters, each community chose a general format for the discussions, established course-specific learning objectives (Table 1), and created a framework for homework, in-class, and project assignments. The basic process that each community used to design the discussion curricula was similar, but the speed of progress and outcomes varied among groups, and each was informed about the decisions of the other group to facilitate coordination. Each community focused early meetings on making decisions about the general format of individual discussions (discussing a paper, doing computer simulations, etc.) and the nature of the graded assignments (homework, in-class, final project, etc.). The OEB group moved more quickly through the initial stages, so they were the first to come up with the general vision and goals for their discussions. They decided that students in the OEB discussions would work on small group activities related to experimental design and data interpretation. The CMB group took this into account and chose a focus for their discussions that would complement and build on what was being done in the OEB discussions. The CMB discussions were ultimately designed to focus on scientific argumentation, particularly those found in the results and discussion sections (Van Lacum, Ossevoort & Goedhart, 2014). Once these general goals were established, each community narrowed down the content or learning objectives that would be covered in the discussions. Each group used a 'backward design' approach to designing the discussions, which involved forming course learning objectives before planning activities or assessments (Wiggins & McTighe, 1998). The OEB group found that they needed to create more specific learning objectives to the broader learning objectives to aid in planning the actual activities for the discussions (Table 1).

In many cases, the curriculum creation took the form of "homework" assignments that were assigned to individual community members and then discussed at the next meeting. For example, the OEB group was tasked with brainstorming learning objectives for the discussion individually, and then came together to share and sort their ideas. Both the OEB and CMB groups often decided on a topic and then assigned group members to find research articles related to that topic to bring to the next meeting to share. This helped to identify articles that were more or less useful for the discussions, and develop standards for what types of articles would work for the sessions. Often articles were chosen based on the ease with which the group thought freshman would be able to interpret the figures in the papers.

During fall semester there were two "mega-community" meetings, where all the communities met together to share the progress they had made. These meetings were extremely important during the early stages for identifying commonalities and differences in the communities' ideas and discussing ways to make the discussion courses cohesive. Based on feedback generated during these meetings and from an anonymous online survey of community members at the end of Fall 2013 (Table 2), several changes were implemented for spring semester. First, it was clear that the majority of community members wanted leadership, so from then on one member volunteered to lead each community. The OEB community had already designated an official leader in the fall (a non-tenure track faculty member who taught an OEB lecture), so she took on the leadership role in the spring. In the CMB community, a tenured faculty member who taught a CMB lecture volunteered to lead the group. Second, many CMB community members expressed frustration over the lack of consistent attendance at their meetings and attributed their

slower progress to this problem. In an attempt to alleviate that problem, several new members were recruited to join the CMB community. In order to provide more support and communication between communities, the community leaders met regularly during the spring semester. These regular check-ins helped to ensure that the curricula being developed in the separate communities would be more cohesive and complementary, which was important given that they were both a part of the introductory series.

Overall, community membership remained fairly stable, but there were several members who stopped attending in the fall and others who could not continue to participate in the spring. Most of those who did not continue in the spring were graduate students or undergraduate students who became too busy with coursework or other degree requirements to continue. A message to the departments recruited additional community members to replace these participants. Faculty and postdoc participation remained relatively stable across both semesters. In the spring, there were 9 members in the OEB community and 7 members in the CMB community. During spring semester the communities continued refining their learning objectives and came up with general ideas for activities and assessments aligned with each objective. Next the groups chose the topics and scientific articles that could be used for each part of the course. To do this, group members searched for articles outside of the meetings and brought summaries to review during the meetings. The process of vetting scientific articles that were appropriate for introductory biology students took considerably longer than expected, so the communities did not finish planning all of the activities and assignments by the end of spring semester.

At the end of April 2014, the curriculum community held an informal poster session where each community presented the activities and ideas they had generated for each discussion. In addition to the curriculum community members, faculty, staff, graduate students and post-docs from the biology departments were invited to attend. The poster session was framed as a celebration to recognize and thank the community members for their work on curriculum design.

Curriculum Design Outcomes

To collect data on the community curriculum approach, we investigated two questions about the creation of the new curricula: 1) how the community members viewed the design process and outcomes, and 2) what was accomplished by the community over two semesters. We used surveys for the first question and artifact analysis for the latter question, thus characterizing the process outcomes from multiple perspectives.

Community member survey

To collect community member perceptions of the curriculum design process and outcomes, survey data were collected anonymously from community members in December of 2013 (six open-ended online questions) and May 2014 (eight open-ended online questions). The survey questions are shown in Table 2. In the fall, for example, community members were asked why they had volunteered, whether the experience had met their expectations, and what had worked and not worked with the communities so far. In the spring, the community was asked about their satisfaction again, as well as what they had and had not accomplished, what they thought about the new curriculum, and what they thought about the process of designing curricula as a community. Responses to each question underwent thematic analysis to identify the themes that were expressed by the group across all questions (Creswell, 2013; Libarkin and Kurdziel, 2002). One researcher read the responses to each question repeatedly and took notes on ideas that seemed to be emerging from the data for each question. That researcher then consolidated those ideas into categories that were emerging from the data as a whole and then coded responses to each question using those themes. A second researcher then acquired the themes from the first researcher and reviewed the participant responses to see if they agreed with the sorting of the responses into those categories. Discussion between the two researchers confirmed the thematic groups.

Community artifacts

To document the progress that each community made on the curricula over two semesters, the notes from each meeting that had been uploaded to a common group site by the GRA were reviewed. Besides meeting notes, learning objective lists, scientific articles, and mega-community meeting notes and outcomes were also available for review. We analyzed all curriculum-related documents and materials that each community had produced by the end of spring semester 2014 and created a list of curriculum aspects that each group talked about over the two semesters. We then compiled a checklist that indicated whether each group had finished, partially finished, or not finished each of those curriculum aspects by the end of the two semesters. All work done after spring 2014 was not considered a product of the curriculum communities.

RESULTS

Community member survey

The results of the community member surveys (N = 13 community members in December of 2013 and N = 11 participants in May 2014) revealed why participants became involved in the communities and their thoughts about the process of curriculum creation. Participants articulated three reasons for why they participated in the curriculum design: 1) they felt it was important to have a voice in the process, 2) they wanted to help improve undergraduate education, and 3) they wanted to learn more about curriculum design and reform. For example, one participant stated, *"I volunteered to participate because I wanted to become involved in designing/reforming the curriculum for general biology classes. I wanted to be able to voice my opinion and give ideas to further improve the curriculum, as we are aware that changes need to be made."* Another participant said, *"I wanted to help undergraduates get the very best possible experience in* [the courses]. *Having recently taken the courses, I feel that I could offer first-hand experience that could benefit our group…what worked, what didn't."* Another participant said, *"I was interested in learning about the process by which curriculum is*

created and evaluated. I would like to use many of the techniques and ideas I have learned here in my own teaching career."

When surveyed in both December 2013 and May 2014, participants felt that the curriculum communities had, for the most part, met their expectations. Participants expressed that the curriculum design process was slow at first, but they felt confident in the amount of work they were able to accomplish later in the semester. One participant stated, "*My [group] was a little slow going at first, but after a couple meetings we began to come up with a vision for how we wanted to redesign the course and what goals we wanted to meet when teaching the subject material."* Although they felt the community structure was effective overall, they wanted more leadership. One participant said, "*The small group I was in has been great for the most part, but…I think the reason* [we] *had so much trouble getting started is because we didn't have anyone serving as a leader. It may have been better to assign roles from the beginning.'* Members enjoyed the mixed, small group communities and the pre-defined goals, but several community members felt more faculty participation was necessary. One community member stated, "*Participation met my expectations in terms of a learning experience, but I was disappointed with the low-participation by instructors."* They also expressed that the communities offered them the freedom to explore curriculum design. As one participant said, "*I also like the amount of freedom we have been given to design the discussions."*

At the end of spring semester 2014, the community members felt that they had accomplished their goals by successfully finishing the framework of each discussion, but recognized that they still needed to finalize the details of the specific lesson plans. One member said, "*We still need to create the detailed lesson plans for modules 2, 3, and 4."* Participants also stated that it would be helpful to have clear rules and expectations stated in the beginning of the process that could facilitate role definition for the members. As one participant stated, "*Establish clear rules and expectations from the beginning. I feel we spent quite some time just figuring out what it is that we are supposed to develop."* The community members expressed that faculty participation was crucial, as well as participation at all levels (undergraduates, graduates, post-docs) in each of the communities. For example, one member stated, *"There needs to be much greater involvement by the faculty who will be teaching the course."* Another member said, *"Getting all viewpoints* [faculty, postdocs, graduate and undergraduate students] *makes sure as much is covered as possible and is essential for success."*

At the conclusion of the academic year, community members were satisfied with the overall structure of the discussions and lesson plans. One participant said, "*I think the structured framework will help bring students up to speed that don't have those skills."* They were also pleased with the active role the students in these discussions would be taking in their own learning and felt this would lead to improved student learning. As one member stated, "*The discussions provide a much more active atmosphere. Being able to put ideas into the context of current research and at the same time learning the process of scientific research, is great!"* Although members expressed concern about whether students would be prepared for the demands of the new discussions and unanticipated logistical issues that would arise during implementation, they acknowledged that such issues were likely inevitable with any new curriculum. For example, one member said, "*I am concerned about the discussion sections. Since they have never been done before unforeseen problems are inevitable."*

Community artifact results

Neither of the communities had fully completed their curricula by the end of spring semester (Table 3). They had each completed draft syllabi for their discussion, including the module topics and topics for each discussion class meeting, the general approach to class activities, assessment types and point values, and learning objectives. However, the OEB community had also detailed the specific learning objectives for each main learning objective, while the CMB community had not.

By the end of spring semester, the OEB community had selected 22 potential scientific articles that were vetted for appropriateness of content and accessibility of methods and results to undergraduate students. The community had tentatively assigned scientific papers to each week of the course, and had developed detailed lesson plans, including homework and reading assignments, in-class activities, and detailed instructions for how the TA would lead each lesson, for the first three weeks of the semester (Table 3). The CMB community had produced an outline of each lesson for the first three weeks (including homework) with potential articles that could be used as part of the daily activities; they had also discussed what types of questions would be asked on the module assessment. However, these ideas had not been formalized into complete lessons as they had for the OEB community. They had discussed activities for each class meeting of the rest of the semester, and started to look for articles to use for those sessions, but had not yet identified the specific articles they would use. Although each community knew the general idea for the final project, they had not formalized specific plans for this module.

To complete the curricula, two to three volunteers continued to work together to write the detailed daily activities and homework over summer and the 2014-2015 academic year. Drafts were produced and continued to be edited by the course leaders and TAs as each lesson was delivered.

DISCUSSION

Overall, the communities succeeded in doing much of the intellectual work to create the new discussion curricula; the discussions now being implemented are clearly reflections of the ideas generated by the curriculum communities. Moreover, each community maintained participants across all academic levels, who worked together throughout the process of developing the new curricula. The perspectives of the graduate students who would be teaching the discussions, and the undergraduates who could more easily envision participating in them, were an invaluable contribution that would have been lost if only faculty had been involved in the process. The community members valued the process and were pleased that they were able to contribute to undergraduate education.

This suggests that when considering broad-scale reform of multi-instructor introductory courses, that a

community approach may be one way to foster a grassroots approach to reform (Henderson, Finkelstein, & Beach, 2010; Henderson, Beach, & Finkelstein, 2011). This approach helps assure that single instructors are not the sole driving force behind the learning objectives, activities, and assessments, and may make it more likely that a consensus curriculum more people agree on will be adopted. This is perhaps particularly important when dealing with course components that will be delivered by TAs instead of faculty. Including TAs in the curriculum design process helps them feel invested in course delivery aspects that they typically have little control over.

Several other curriculum development efforts have involved student partners as paid consultants or fellows (e.g., Cook-Sather, 2014; Bovill, Morss, & Bully, 2009; Woolmer et al. 2016). We did not offer paid positions to undergraduate students who were part of the curriculum communities, but we were able to get enough participation by offering students course credit to compensate them for their time. This suggests that students are willing to be partners in curriculum design as essentially volunteers versus being paid. It is important to highlight, however, that our undergraduates were mostly recruited from our existing lab assistant program, so they were undergraduates already committed to teaching and learning in introductory biology courses.

One benefit of engaging students in partnerships with faculty is that it breaks the traditional hierarchies that usually define academic relationships. The undergraduate students who participated in our communities were not only interacting with faculty, but also graduate students and postdocs. This provided an opportunity for even more communication across academic tiers. We carefully considered this when forming the groups and emphasized many times that there was no leader in the group and everyone was equal. Yet, at mid-semester the groups indicated that they wanted a leader, and in all groups, the leader ended up being a faculty member. This may suggest that there is a certain amount of unease with the breaking of traditional hierarchies, and that more aggressive approaches need to be taken if a truly equal group is desired as part of the design process.

Bernstein & Greenhoot (2014) found that teams made up of faculty, graduate student fellows and teaching, library and writing specialists were able to design high-quality and impactful curricular changes in undergraduate courses that likely would not have been possible if faculty members were acting alone. Although we have little evidence to support this claim, we feel strongly that the level of detail and rigor in the curriculum our communities created would not have resulted if faculty were designing the curriculum in isolation. Thus, we agree with Bernstein & Greenhoot (2014) that these teams are effective for curriculum design. Every time the groups met, different members brought ideas to the table that would not have existed without the groups we formed, and the members bringing ideas were most often not the faculty, but the more junior members of the groups.

The community approach to curriculum design could also potentially be applied to the process of revising courses as well. Standing committees of community members could be set up each year to oversee implementation of introductory courses, collect data on student learning and make revisions as needed. This ongoing investment of undergraduates, graduate students, postdocs, and faculty would be one way to make certain that the course maintains its original focus on student learning objectives and uses data to make revisions over time. This would also provide an ongoing mechanism for graduate students, undergraduates, and postdoctoral researchers to gain critical experience with curriculum development and ongoing implementation.

Given what we learned about how each community functioned, we can offer some suggestions for others trying this approach. One is that there should be meaningful faculty involvement, particularly from faculty teaching the course being reformed, in each group. Clearly, members of our groups looked to faculty for leadership and direction. In the case of our curriculum revision, faculty of the courses in this project established that they wanted to focus on process skills and work with primary literature. Second, it is important that leaders are established for each group, but that their role is not to dictate results but rather to set achievable goals for each meeting, and to give group members clear tasks that they can work on. In our case, groups made more progress when leaders prioritized goals and decisions while keeping their eye on the big picture. This established leadership can also smooth over transitions of semesters when some group members leave and new group members are added; it provides consistency even when the assemblage changes. Designing curriculum is often a slow process and community members in our study were surprised by how long it took to make progress. It would be helpful to set clear expectations about this from the beginning to prevent frustration. Finally, some consistency in membership and cross-talk among different communities (such as with our mega-community meetings and meetings of community leaders) helped everyone to be on the same page about the curriculum. The communication and coordination between the groups kept the groups focused, motivated to make progress each month, and consistent in the course design.

This paper describes our community-based approach to curriculum design in detail, but we cannot comment on its effectiveness relative to other approaches because we did not set out to test this question. Nor was there a former discussion curriculum for these courses that we could compare the new curriculum to. To evaluate the effectiveness of a community-based approach, future studies should compare a community-based approach with other models of curriculum reform to see whether one achieves a more effective curriculum design than another. We also did not report on student learning in the discussions designed by the communities. Data were collected on student learning in the OEB and CMB courses before and after the discussion sections were added, but they are presented in a separate study (Auerbach & Schussler, 2017). It is also unknown whether this approach would have been just as effective in designing a lecture class approach taught by faculty versus a discussion section class taught by graduate students. It is possible that the commitment of graduate students was higher for our process because it was a course they would potentially be teaching.

The approach we took to employ a team to design curriculum, that included multiple levels of the academic

community, and with a grassroots approach to curriculum, is not new in the literature, but is not often used to create TA-led small group science discussions. Thus, this study adds to a literature base suggesting that this approach works to design quality curriculum, and that the disciplinary area does not limit its effectiveness. Given that the existing literature has applied this model both inside and outside the U.S., it also is not restricted to particular countries to be effective. If biology departments are going to meet the goals of the *Vision and Change* recommendations, a larger part of the academic community needs to embrace the suggested changes to introductory curricula and instruction. Although faculty are an important part of this process, involving multiple levels of the academic community will have a larger impact over time. Not only will the impact be greater, but the resulting curricula will better represent the community it serves and hopefully reflect a renewed focus on undergraduate student learning.

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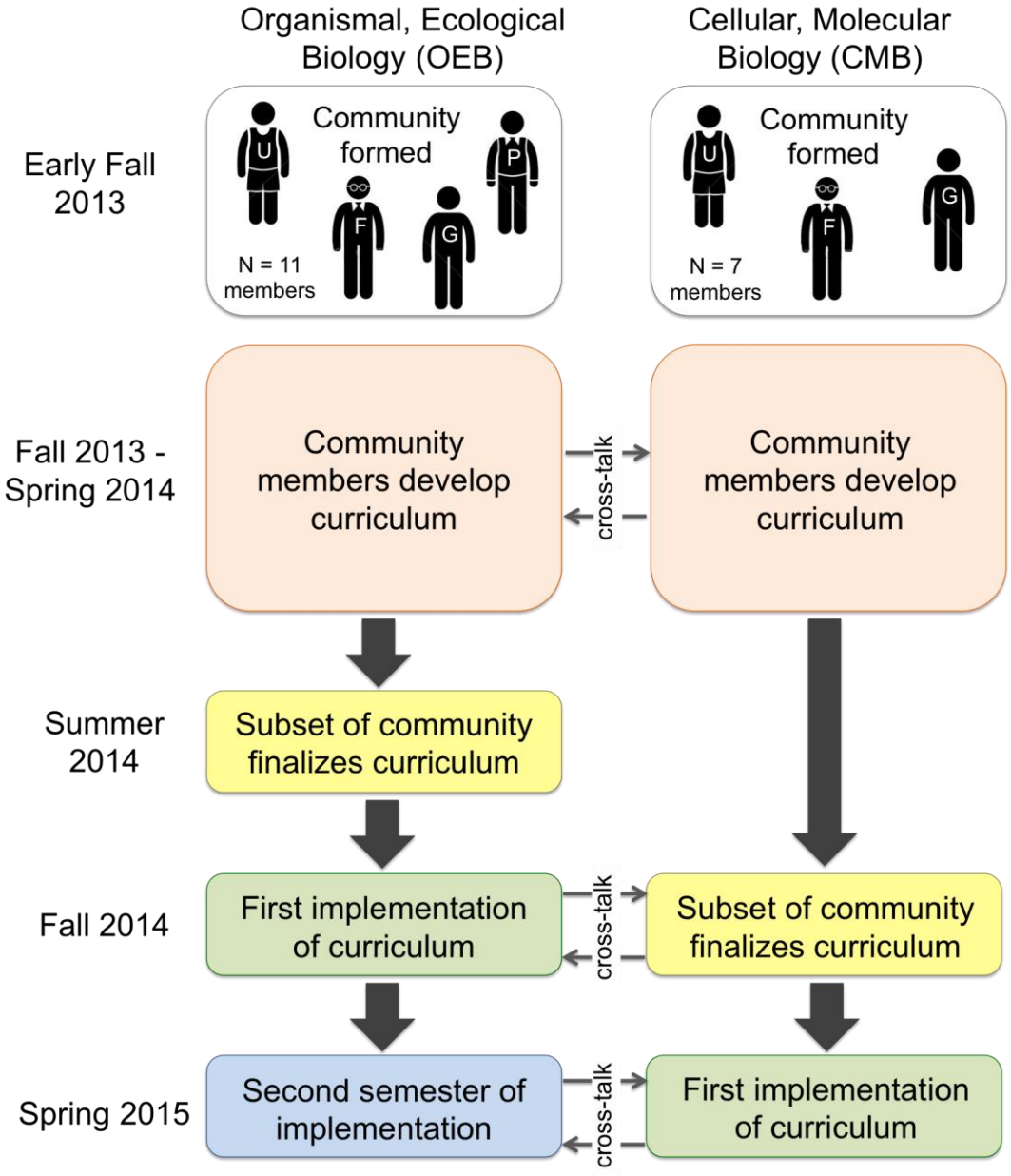
APPENDIX A

Figure 1. Timeline and process of the community curriculum design.



APPENDIX B

Table 1. The learning objectives that the curriculum communities created for the OEB and CMB courses. The more specific learning objectives for the last OEB learning objective (in italics) demonstrate how the broad learning objectives were expanded into more narrow learning objectives for the purposes of lesson design.

Course	Learning Objectives
OEB	Read, interpret and evaluate scientific literature
	Interpret figures
	Identify the purpose of a scientific study
	Synthesize scientific results and draw conclusions
	Describe and evaluate a study's methods
	Use a model to describe a system and make predictions
	Identify important components of a system and how they interact
	Develop a simple visual model to describe a system or hypothesis
	Translate a graph into a visual model
	Use a simple visual model to make predictions
	List the assumptions of a model
CMB	Write and analyze scientific arguments from data
	Use an argument to make predictions about future research directions
	Explain the contribution of multiple sets of data and arguments to the progression of scientific knowledge
	Articulate an understanding of the cellular and molecular aspects of DNA, photosynthesis, and disease

Table 2. Survey questions asked of community participants in the fall and spring.

Semester	Questions
Fall 2013 (N = 13)	
	1. Why did you volunteer to participate in the CUBE curriculum reform process?
	2. Has participating in the CUBE curriculum reform process met your expectations? Why or why not?
	3. What reflections do you have about the use of a community (from undergrads through faculty) to create new curriculum?
	4. Finally, because this is a new process for all of us, what HAS worked about this process and should be retained (you can reflect on what HASN'T below!)
	5. ...And what has NOT worked? (What, if anything, should we change for the spring?)
	6. Is there anything else you'd like to tell us?
Spring 2014 (N = 11)	
	1. Do you think your community group accomplished what it was supposed to this year?
	2. In your mind, what, if anything, still needs to be done? (We will use these thoughts to guide our activities this summer)
	3. What were you expecting to gain from participating in a community curriculum group this year?
	4. Has participating in the CUBE curriculum reform process met your expectations? Why or why not?
	5. What reflections do you have about the use of a community (from undergrads through faculty) to create new curriculum?
	6. What parts of the new curriculum are you particularly excited about students experiencing?
	7. What parts of the new curriculum (or its implementation) are you worried / concerned about?
	8. Is there anything else you'd like to tell us?

Table 3. Important outcomes that served as part of the discussion curricula are listed. For each community, the checks indicate whether the task was finished and used with few changes, only partially finished (or used with more significant changes), or not finished, meaning the task was not done or was completely replaced by something new in the final curriculum.

	OEB Community			CMB Community		
Course aspect	Finished	Partially finished	Not finished	Finished	Partially finished	Not finished
Module structure and topics	X			X		
Draft syllabus	X			X		
Learning objectives	X			X		
Specific learning objectives	X					X
Assessment types and point values	X			X		
Detailed lesson plans		X			X	
Assessments (homework and in-class)		X				X
Scientific articles		X			X	
Final project assignment details			X			X