Planning for the Long Term

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Name of Institution	Bates College
Size	about 1750 students
Institution Type	small 4-year private college
Student Demographic	students elect this course for their math major or minor, biology major, or Gen Ed quantitative requirement
Department Structure	Mathematics and Biology are individual departments in the College

Abstract

Bates College offered its first mathematical biology course in 1995. Over time, the student population and involvement of faculty have changed. Our recent redesign process yields suggestions for any mathematical biology course in its early years. We share those suggestions with you in this essay.

Course Structure

- Weeks per term: 12-week semester
- Classes per week/type/length: Three 55-minute or two 80-minute lecture periods each week
- Average class size: 25-30 students in one section
- Enrollment requirements: There is a Calculus 1 prerequisite
- Faculty/dept per class, TAs: One mathematics instructor
- Next course: None

Introduction

Many mathematics faculty members are extremely enthusiastic these days. We are working together with our colleagues in biology, and perhaps other sciences, to create and teach new mathematical biology courses. What will result from our efforts after five years go by? Ten? More? Will our mathematical biology courses remain vital, current, cross-disciplinary, engaging? Many aspects of these courses, given careful attention from the start, can help us attain long-lived, healthy mathematical biology courses that are still going strong many years from now.

Bates College offered its first Mathematical Models in Biology (MMB) course in early 1995. It changed significantly over the years, and our most recent process for updating it sheds light on long-term issues facing mathematical biology courses.

Bates is a liberal arts college in Maine with an enrollment of about 1750 students. General education requirements in 1995 included a quantitative course and three courses in the natural sciences. MMB satisfied both these requirements, along with serving as an elective for the biology major and for the mathematics minor. Many students at Bates aim to graduate with as many credentials as possible, whether

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multiple majors, several minors, or unusual student research experiences with Bates faculty. To best achieve their many goals, students seek the most efficient way to satisfy their general education requirements. When they can complete several requirements with a single course, they sometimes jump in, regardless of their interest in the course and their own background. MMB was offered as an introductory-level course, with no prerequisite, only a suggestion that students take some other biology course first. Therefore a single class could mix students having an astounding, and daunting, mix of backgrounds.

MMB began as a cross-disciplinary project, engaging both the Mathematics and Biology Departments, equally and actively. Over the years, mathematics faculty became the exclusive teachers of the course, and the Biology Department's connection lessened correspondingly. The biology topics in the course were not updated as often or as thoroughly as they might have been. Biology students, deciding which courses to take, received less and less advice regarding MMB.

As a result, Bates decided to restructure, even recreate, MMB. We know what pitfalls came about last time, and we have plans in mind to keep them from recurring. By sharing our past and present experiences with our readers, we hope to share ideas for keeping mathematical biology courses robust for a very long time.

Description

The story began in 1993. A biology professor and two mathematics professors began to talk about incorporating more mathematics into an introductory biology course. They wrote, and were awarded, an NSF grant to do that. Students in the biology class were eager, embracing mathematics in the context of their biology labs. As a result, the three professors wrote a proposal to develop a biomathematics course.

The proposal went to the Howard Hughes Medical Institute grant at Bates, an ideal source for funding this sort of curriculum development project. During the review process, the group of professors associated with the project changed. The new group had four professors, with only one from the original group. The biologist was replaced with two different biologists; one mathematician remained, and a statistician joined. This group met regularly during Winter 1994. They continued through the summer, joined by two students they had hired. Those students stayed on as teaching assistants the first time the new course was taught, Winter 1995. (Bates, located in Maine, has a winter semester rather than a spring semester.)

During the planning process, the group discussed and debated the central focus of the course. It would have been easy to view mathematics as a toolbox for biology. Instead, the group opted to give center stage to both mathematics and biology. To that end, they created a course on mathematical models of biological processes. Creating, analyzing, and visualizing models, along with data collection, gave many opportunities for studying mathematics and statistics. Mathematical topics included linear and nonlinear population modeling, Markov and Leslie models, matrices, eigenvalues, and eigenvectors, among others. At the same time, a variety of biological concepts played a part. These included predator-prey systems, models for immune systems, molecular evolution, and phylogenetic trees.

Besides specific topics, computer use, typically Minitab and MATLAB, was a focus. Furthermore, the earliest iterations of the course emphasized service learning. Students went into nearby hospitals in small groups. They worked with administrators and analyzed data using techniques they had learned in the class. They experienced firsthand the connections between classroom learning and its applicability in the community.

Since 1995, MMB has undergone several changes. Originally there was a heavy emphasis on statistics, but this was reduced to allow time for extended service learning projects, or for other topics. The course began with professor-created modules in Minitab and MATLAB; over time, new software updates mandated module updates, and students were hired to create new modules during the summer.

The bigger issue was student change. In its first few offerings, the course drew eight to twelve students. In later offerings, class sizes ranged from twenty-four to thirty. It is hard enough to arrange service learning

opportunities for eight to twelve students, and more so for much larger class sizes. As a result, service learning has not been part of the course in recent years.

The student profile for the course has also changed. Originally, students were biology majors with an interest in mathematics, or vice versa. MMB is cross-listed, counting for both mathematics and biology credit. Since each department had several faculty members very involved with the course, each department regularly advised students to take it, and faculty members in each department knew a lot about the course and could answer questions about it. As time went by, biology faculty members had less connection to the course and less ability to advise their students to take it. In recent years, biology students have rarely been advised to take the course, and the biology faculty members have known very little about how the course is run. In fact, all three biology faculty members who were once involved have now retired or moved on to other jobs. No one remains in biology who was directly connected with the original MMB.

This course was designated from the start to fulfill multiple general education requirements. At the time, this made sense because mathematical biology was largely unheard of, and students were more likely to take the course having the extra encouragement of satisfying some of their requirements. Over the years, however, students with no interest in the subject began taking the course merely to satisfy multiple requirements. Some of them had such minimal mathematical background that they could not keep up with the most basic algebra steps; they did not mesh well with senior mathematics and physics majors. Other students proudly stated that they neither knew nor cared about mathematical biology, and were taking this course only because it satisfied multiple general education requirements. For these reasons and more, it became difficult to lead classes that were appropriate for all, or even most, of the students.

Discussion

One goal of the original MMB was accessibility to all. For that reason, the course had no prerequisites. Since then, increased pre-college access to calculus courses has meant that the vast majority of Bates students arrive with some prior exposure to calculus. We thus felt confident requiring a Calculus 1 prerequisite for MMB. We also gave MMB a 200-level course number instead of a 100-level number. The changes allow us to include a wider range of mathematics in the course while suggesting to registering students that they will need to remember their earlier mathematics classes in order to succeed in this course.

We also knew to think carefully about general education requirements. As it happens, Bates changed them starting with students entering the college in 2007. That made this an ideal time to change the set of requirements satisfied by MMB. Our new system prescribes different rules for "double-dipping" (or "triple-dipping") - satisfying two (or three) requirements with a single course. In the new system, we can still designate MMB as counting toward multiple requirements. However, students can no longer use it to fulfill all the requirements it theoretically can satisfy. So, for example, students must decide whether this will count as their scientific reasoning credit or their quantitative literacy credit. Our vision was that this would keep the course appeal broad without drawing undue numbers of students who claim to have no interest in either mathematics or biology. The course is currently being offered for the second time in its new incarnation, and both times, there has been a pleasant mix of students with majors across the sciences. Almost all appear very interested in mathematical biology.

Meanwhile, we have re-devoted ourselves to making sure that MMB deserves its cross-listing in the mathematics and biology departments. We have had several discussions with biology faculty members on this. Our goal was to tie the newly-designed MMB to examples from the introductory biology course offered each year at Bates and to examples from upper-level biology courses. The connections serve many purposes: we can use MMB to advertise subsequent biology and mathematics courses, advising students that the topics are covered in greater depth in later courses. Team-teaching is not a possibility right away, with MMB continuing to be taught mainly by the mathematics department, but the new structure makes it easier for biology faculty to speak in MMB as guests. Some of our examples tie in to the expertise of Bates biologists, students benefit from the expertise of many faculty members, and our department connections continue to grow. Furthermore, both departments will feel secure in counting MMB toward their major.

We have retained many of the central mathematical and biological topics from earlier incarnations of MMB, yet left room for individual instructor preferences and unique opportunities to invite guest speakers. Our course now centers mathematically on population models using difference equations, differential equations, matrices, eigenvalues and eigenvectors, and Markov approaches. Biologically, we focus on single-species population growth, multiple-species interactions, and epidemiological models. Optional topics include phylogenetic trees, vaccination theory, game theory, spatially distributed phenomena, and cellular automata. Additional topics may be generated by student projects that help us to address specific student interests that may have been the main reason a student registered for this class. Regardless of their origin, the class examines all topics from the viewpoints of biological reasoning, mathematical theory, and computer simulation of model outcomes.

In the long term, we will maintain our mathematics-biology connections and nurture new connections over time. We need ways of staying in contact, staying current with each other's research, and meeting new and visiting faculty members as they arrive. This is not always easy, we admit, but we have already implemented several strategies:

- I began auditing biology courses, and faculty from other Natural Sciences departments have audited all or part of the new MMB. Besides gaining a glimpse into each others' courses by doing this, we discover opportunities for working together in the future.
- We held several joint meetings of a mathematics course (Differential Equations) and a biology course (Epidemiology) after the outbreak of H1N1 at Bates in Fall 2009. The students and faculty members involved had to explain their approaches to each other and combine areas of expertise to better track the timing and reasons for the outbreak. The project strengthened faculty collaboration and introduced a wider range of students to the possibilities of mathematical biology, which helped us to advertise future offerings of MMB. We plan more collaborations of this type for future semesters.
- The departments in the Natural Sciences and Mathematics Division at Bates have held several joint meetings to discuss curricular issues affecting students at all levels. These meetings initially felt like introductions of each department to the others. Now, however, they function as an ongoing conversation among the departments as entities, and among the faculty members making up the departments. We all know much more about what is happening in each others' courses, and we continually seek to further connect our courses. We plan to continue these meetings.

Despite the increase in cross-departmental collaborations, we have only a small number of faculty members even potentially involved in mathematical biology. With so few people, it has been hard to create consistent mathematical biology programming. To address this, Bates teamed up with two nearby small colleges, Bowdoin and Colby, for a series of mathematical biology events in the 2007-2008 academic year. We held a mathematical biology seminar series, funded by a grant from the Mellon Collaborative. Faculty from each of the colleges spoke, typically at a college other than their home institution, about their research in mathematics or biology. Talks did not need to be cross-disciplinary: the goal was to share our research with a general faculty audience. Seminars were preceded by refreshments and followed by a social hour or dinner, giving us all a chance to talk about our work. The overwhelming response to this was that we finally had a critical mass: many faculty members at each of the colleges, and in several departments at each college, had interests in mathematical biology, and the seminar series provided a way and a reason to communicate regularly.

In the few years since, the speaker series coordinators from each of Bates, Bowdoin, and Colby have maintained contact, letting each other know about mathematical biology events at their own colleges and discussing future collaborations on research or grant proposals. We all work, as always, to further the mathematical biology connections within our own colleges, yet having this larger pool of people to work with adds even more opportunity.

Suggestions

All in all, we now have the benefit of experience on our side. We have concrete approaches regarding prerequisites, satisfying requirements, and long-term viability of a course requiring input from many faculty with many areas of expertise.

To summarize some specific plans:

1. Use prerequisites, or other institutional structures, to allow an appropriate class mix (years, abilities, etc.) while keeping the course available to the students you hope will take it.
2. Think from the start about building, and maintaining, connections with faculty and courses across disciplines. Team-teaching and guest lectures are ideal if you can arrange them. Overlapping topics between biology and mathematics courses are additional ways to promote the interrelatedness of these fields.
3. Seek out ways to enlarge, engage, and sustain your bio/math community. This may mean connecting with nearby colleges, arranging interdisciplinary seminars within your own institution, seeking partnerships with nearby industries, or any other activities that work best at your own institution.

We wish much luck – and creativity! – for those involved with mathematical biology courses.

References

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