

SEI: Increasing Teaching Effectiveness in Ecology and Evolutionary Biology

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Scientists take pleasure in doing science because we explore phenomena that interest us, ask questions, pose hypotheses, design experiments to test our hypotheses, and write about our findings for a broader audience. If we redesigned our...courses to be more similar to what we like about science, then perhaps our students would far exceed our expectations for investigating the world in a passionate and meaningful way.

(Coil et al. 2010)

Synopsis

The Department of Ecology and Evolutionary Biology (EBIO) will significantly improve teaching effectiveness through activities supported by the Science Education Initiative. Our objectives for the proposed three-year plan are as follows:

- 1) In collaboration with EBIO faculty and students, affiliated science departments with vested interests in the EBIO curriculum, and scientists from the local community, we will *formulate learning goals* across three EBIO core courses;
- 2) *Implement learning goals* through the development of effective assessments and learning activities resulting from the cooperative activities of faculty and science teaching fellows;
- 3) *Assess education effectiveness* using multiple lines of evidence, including, but not limited to, collection and analysis of data from pre- and post-assessments, peer review, student interviews, and formative assessments.

The EBIO department met a number of times for developing the scope and ideas in this grant. Importantly, there was broad enthusiasm for transforming our education mission and activities. *All EBIO faculty members have formally pledged their dedication to achieving the goals of this SEI proposal. Additionally, the EBIO department faculty voted unanimously in support of this SEI proposal.* Although early versions of the proposal included seven different large-enrollment courses with laboratory sections, we established priorities for our planned transformative activities with the first priority being the three classes beyond the introductory General Biology courses that form the core of our major.

The proposed budget chiefly funds two postdoctoral STFs as well as summer salary for four faculty members, course buy-out to allow for team teaching, and for professional, independent peer review of the proposed SEI-funded revision of the EBIO teaching mission. Additional travel funds will provide support to the STFs for professional development.

The Department

The department of Ecology and Evolutionary Biology has 33 faculty members. Over the last 5 years the number of declared majors has declined somewhat, reaching a minimum in 2007, but has increased steadily since then (Figure 1). According to Deans Beatty and Gleason, EBIO now generates the *most* credit hours per tenure-track faculty line of any of CU's natural science departments.

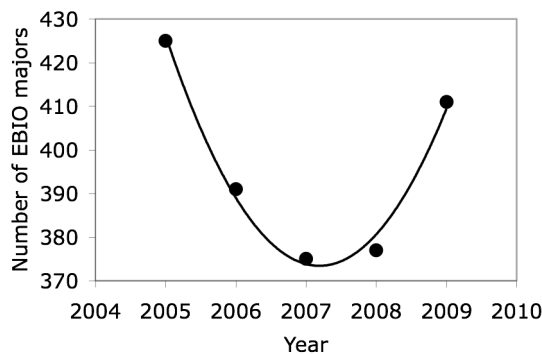


Figure 1. The number of undergraduate students that declared an EBIO major for the last 5 years (prior to 2010).

The current EBIO undergraduate curriculum reflects our collective perspective about the fundamental knowledge and concepts necessary for students in this broad field of biology. There are five courses that all EBIO major students take: General Biology 1 and 2, Ecology, Genetics, and Evolution. General Biology 1 and 2 (EBIO 1210 and 1220) are multi-topic courses designed to expose students to the breadth and science of biology. These two courses serve approximately

1450 to 1550 students each semester, and an additional 100 students in the summer. Of these students, only about 7% comprise declared EBIO majors; 93% of the students come from other departments, mostly from Psychology (PSYC) and Integrative Physiology (IPHY), and includes a large fraction of students that have not yet declared a major. The latter three courses (Ecology [EBIO 2040], Genetics [EBIO 2070], and Evolutionary Biology [EBIO 3080]) constitute the central core curriculum for EBIO majors.

Targeted Courses

The faculty met and discussed the scope of education transformation necessary within the department. These meetings were very well attended (by about half the faculty). More importantly, many faculty members expressed an interest in participating in the proposed SEI-funded activities. In fact, the original plan included an emphasis on 7 different courses, all large-enrollment courses with laboratory sections taught by multiple instructors. The list included the five courses required for the major *and* two upper-division elective classes: Animal Behavior (EBIO 3040) and Microbiology (EBIO 3400). However, given the scope of activities required for transforming a single course, we decided to focus first on the three EBIO core curriculum courses: Ecology (EBIO 2040), Genetics (EBIO 2070), and Evolutionary Biology (EBIO 3080).

Ecology (EBIO 2040) provides an overview of the factors that determine the diversity and abundance of organisms in nature. The course consists of three hours of lecture and three hours of laboratory each week. Three different professors, including two tenured professors, have taught the course over the last two years. Enrollment in the course ranges from 100 to over 200 per semester and the number of enrolled students has steadily increased over the last four years (Figure 2). Both EBIO and ENVS require EBIO 2040 of their majors, and there is almost an equal number of students who have declared EBIO and ENVS in the course (Figure 2).

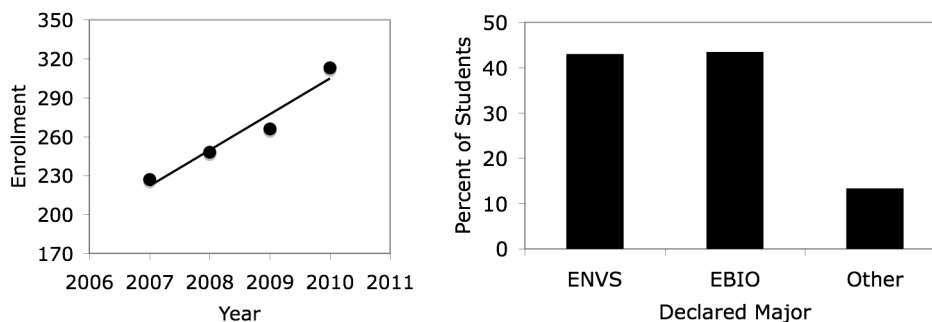


Figure 2. Enrollment in EBIO 2040 over the past 4 years (left). The declared majors of students enrolled in EBIO 2040 from Fall 2010 presented as a percentage of all students enrolled in course (right).

Genetics (EBIO 2070) is a survey course centered on the study of structure and expression of genes, on the rules of inheritance, and on the factors that determine variation in genes within populations. The course typically consists of three credits of lecture and one credit (2 hours per week) of recitation. This course is typically taught once during the academic year (in the spring) and once during the summer. Enrollment has increased over the last 4 years, from about 110 to 150 students (Figure 3). The majority of students ($\geq 70\%$) are EBIO majors.

Evolutionary Biology (EBIO 3080) is focused on ultimate explanations of biological diversity. Two different instructors teach the course, one each semester. There are three hours of lecture and a two-hour lab per week. The laboratory is a key aspect of the course because the activities require students to gain expertise in a variety of analytical approaches appropriate for testing alternative hypotheses. Yearly enrollment in the course has increased from about 100 to over 160 students (Figure 3). The majority of students ($\geq 70\%$) are EBIO majors.

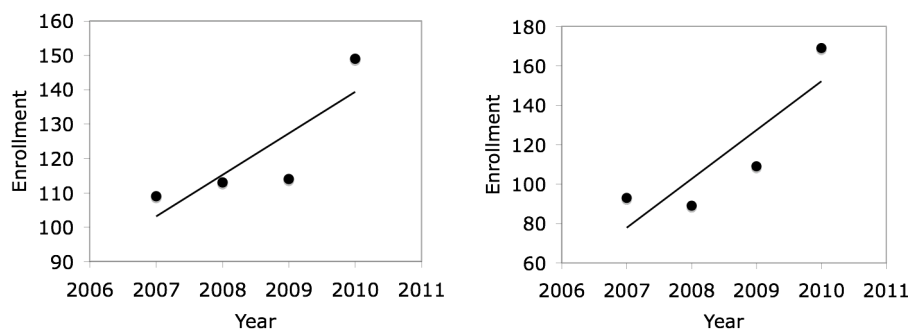


Figure 3. Enrollments for EBIO 2070 (left) and EBIO 3080 (right) over the past 4 years. The yearly enrollment increases for the two courses are 12 and 28, respectively.

The Plan

Our general strategy corresponds to the recommendation that our teaching mission in EBIO change from one in which standard, or professor-centered, course planning design is common to one in which a student-centered course design prevails (Wiggins & McTighe 1998; Wood 2009). The typical procedure for the standard plan is to 1) choose a textbook, 2) create a syllabus, 3) write lectures and prepare PowerPoint slides, and 4) write homework and exams that test knowledge. By contrast, the student-centered approach begins with 1) formulating learning goals, 2) designing appropriate assessments that address the learning goals, and 3) devising learning activities consistent with the learning goals and the assessments (Wood 2009).

Our proposed plan largely follows the “student-centered” approach. First, we will *formulate learning goals*. Second, we will *implement the learning goals* through the design of formative and summative assessments and the preparation of learning activities designed to achieve the learning goals. Third, we will *assess teaching effectiveness* using multiple lines of evidence.

The main focus of our efforts will be on large-enrollment courses with laboratories (or recitations) that form the core curriculum for a major in EBIO. We focus particular attention on courses with laboratory sections because we believe that these courses address three fundamental aspects of a student’s education: cognitive ability, affective learning and psychomotor skill development. There is general recognition of the need to involve undergraduates in the process of research (Commission 1998), and laboratory sections of courses can provide an opportunity to do so. Our goal is to integrate the curriculum in the lecture and laboratory sections of courses and to move from largely “cookbook” laboratory exercises to a focus on scaffolded inquiry-based learning with an emphasis on testing hypotheses. When successful, such strategies can markedly increase in a student’s ability to use science as a way of knowing the world (Lue & Losick 2009); moreover, there is a demonstrated increase in positive attitudes about science (Russell et al. 2007).

Objective 1: Formulate Learning Goals

Formulating learning goals will involve developing specific goals for each course, aligning learning goals between the “lecture” and laboratory sections of courses, and integrating learning goals across the EBIO core curriculum. In effect, we seek a document that describes *what* learning goals should be achieved and *how* and *when* the goals will be learned across the three courses. We will articulate learning goals that include the three domains of learning (cognitive, affective, and psychomotor).

Our approach will emulate successful strategies adopted by Physics (R. Pepper, pers. comm.). Specifically, we will have a series of informal “brown bag” meetings with EBIO faculty to which we will invite various interested faculty from sister departments (e.g. ENVS and IPHY)

and members from the local scientific community (e.g. NCAR, Forest Service, Colorado Division of Wildlife, USFWS, etc). These informal meetings will be used mainly for collecting information and perspectives on what students should be learning in a specific course.

Once we have sufficient information, an EBIO working group will be assembled that includes professors responsible for teaching each particular course, selected senior and junior faculty members, two science teaching fellows, and interested graduate students. (We have a National Science Foundation funded GK12 training program in EBIO and many graduate students have a strong interest in education and outreach.) Participation in this working group will be considered a service responsibility within the department. Assembling a working group should not be a problem; we already have a curriculum committee on which a large number of EBIO faculty members have volunteered to serve which reflects the genuine enthusiasm in the department for our educational mission. A Science Teaching Fellow and a senior faculty member will facilitate the working group meetings. At the end of these meetings, we will have generated a list of learning goals that will be taken to the faculty at-large for evaluation and the establishment of consensus. Once we reach consensus, the working goals will be formalized in a single document and posted on the departmental website. We anticipate revisiting the document annually and editing and revising as necessary.

As a department, we have already begun the process of developing learning goals for the EBIO major. In a recent faculty meeting, we identified quantitative literacy (QL: Speth et al. 2010)—namely, the ability to manipulate equations, and generate and interpret graphs—as an important general learning goal. To achieve this goal, the EBIO department, by a unanimous vote of the faculty, decided to adopt the computer program R for all cases where the manipulation and analysis of data is necessary. Prior to this discussion, our different courses utilized different programs for manipulating data and testing hypotheses (i.e. EXCEL, Jmp, SAS, StatView, R, etc). By moving towards using the same platform for analysis throughout our curriculum, we will be able to develop and integrate curricula across levels, beginning with an introduction to R for basic data manipulation and statistical tests in lower-level introductory courses and more advanced implementation of R in upper-level courses.

The process outlined above will allow for the establishment of learning goals developed through broad-scale faculty participation and consensus. We anticipate that the formulation of learning goals will be completed for all targeted courses during the first year of the SEI grant (see Anticipated Timeline below). Having discussion about learning goals for different courses at the same time should facilitate coordination and integration across courses. The STFs will, in collaboration with particular faculty, coordinate the activities listed above, with a core set of EBIO faculty participating in all discussions of learning goals.

Objective 2: Implement Learning Goals

An overarching goal of the SEI proposal is to advance our ability to teach effectively. We will construct our curriculum around the learning goals such that education becomes student-centered (Wood 2009). Specifically, once we have a set of broad overall learning goals as well as specific goals for individual courses, we can design formative and cumulative assessments that will, in many ways, dictate what we teach and how we prepare and deliver learning activities (Wood 2009).

The faculty members who are part of the development of this proposal have met and discussed ways of improving our teaching. Several important topics have emerged and these topics will be some of the first for discussion during committee meetings and workshops. For instance, we recognize the importance of Bloom's taxonomy (Crowe et al. 2008) as a way of evaluating learning activities, with the ultimate goal of quantifying the cognitive level of our teaching and increasing our emphasis on higher level cognitive performance. Another topic of discussion was whether we want to adopt case-based learning (Knight et al. 2008) such that the core curriculum would focus on a set of biological "cases" (or problems). These specific cases

would be revisited and addressed using different and progressively more sophisticated perspectives consistent with the subject as a student moves from the lower to higher-level courses. In this scenario, there would also be an emphasis on integrating higher-level cognitive processes at all levels. Additionally, we have discussed the development of science *skills* as opposed to conceptual and content *knowledge*, acknowledging the fact that an emphasis on the development of skills poses some challenges. Surveys across a number of institutions have revealed that many science departments recognize the importance of skill development for their students but often fail to achieve desired learning goals because 1) teaching skills is too time consuming, 2) there is a perception that students need more knowledge before they can learn skills, 3) an emphasis on developing skills would require too much time of the professor to change the curriculum, and 4) it is difficult to teach skills (Coil et al. 2010).

What is clear is that *all* professors can, in fact, improve the effectiveness of their teaching with the appropriate training and incentives. Such improvement is evident from case studies: perhaps the most widely known example is a lecture by Eric Mazur entitled “Confession of a Converted Lecturer” (<http://www.youtube.com/watch?v=WwslBPj8GgI>). Mazur’s “converted” approach utilizes clickers and emphasizes peer instruction, a strategy that clearly improves student understanding (Glynn et al. 2006; Smith et al. 2009). There are, of course, many strategies that can and should become part of the teaching toolbox for faculty in EBIO, including, but not limited to, peer instruction with the aid of clicker technology (Smith et al. 2009), an emphasis on creative problem solving (DeHaan 2009), the development of story-telling skills that improves student attention (Overcash 2010), the careful construction and implementation of formative assessment tools (Carrillo-de-la-Pena et al. 2009), the use of “expert” undergraduate learning assistants (Romm et al. 2010), abandoning textbooks and moving towards web-based interaction learning materials (Klymkowsky 2007), and, importantly, effective use of assessment to quantitatively test teaching effectiveness. Our department is already successfully using many of these approaches on an individual-instructor basis. We now propose to incorporate the best teaching practices across the core curriculum with the anticipation that the effective strategies will be implemented in most, if not all, EBIO courses.

The proposed plan is to have faculty work closely with STFs for implementing our learning objectives using the best possible teaching strategies. Each course may require emphasis on different approaches depending on the particular learning objectives. It may be that some courses require an immense investment of time and energy for achieving the desired transformation whereas other courses do not require as much effort. Regardless of the effort required for each course, an overarching goal is to get faculty together with STFs, in working groups, for the purpose of improving how we teach science and how we think about how we teach science (see Specific Plans for STFs below).

Objectives 3: Assess Teaching Effectiveness

Perhaps our most difficult objective is the scientific-based evaluation of teaching effectiveness. Developing and implementing assessment strategies will be important for evaluating the efficacy of the anticipated changes. Thus, we need to assess how well our students attain competency and achieve what our general and specific learning goals are meant to accomplish. We plan to assess the three different learning domains: cognitive, affective, and psychomotor.

Cognitive gain is best assessed using pre- and post-assessment. Critical to the success of such assessment is identification of a limited set of key concepts from the learning goals. With a set of key concepts in hand, we can develop effective questions and will adopt an approach in which assessment questions are embedded in exams. Nonetheless, we will seek guidance from people experienced in doing pre- and post-assessment. One approach will be to use the Critical Thinking Analysis Test implemented by Michael Grant, Associate Vice Chancellor of Undergraduate Education and a faculty member in EBIO. There are also numerous sources of

information about teaching assessment, including an internet site on higher education outcomes assessment (<http://www2.acs.ncsu.edu/UPA/assmt/resource.htm>) maintained by the University of North Carolina.

The Colorado Learning Attitudes in Science Survey (CLASS) provides a means of assessing affective learning. We are already using CLASS as a means of assessing the development of students. In the fall semesters of 2007, 2008, and 2009, the CLASS was administered in EBIO1210 (over the first half of the semester in all four sections in all three years), and the results from these surveys have thus far been used as the basis for comparison for the EBIO-General Biology course (Freshman level) with the outcome of CLASS administration at the next level of courses offered in MCDB (Principles of Genetics at the Freshman/Sophomore level) and IPHY (Human Anatomy at the Sophomore/Junior level). The results of this comparison were presented e.g. at the CUSEI End-of-Year Event, held on May 7, 2009 (see http://www.colorado.edu/sei/end_of_term.htm). Conclusions from this comparison were that 1) “Similar to what has been observed on the Physics and Chemistry CLASS, Biology students tend to shift towards more novice views in introductory courses” and 2) “As the students progress through their biology major, the shifts become similar to experts, but very few of these shifts are significant” (see “The Biology CLASS: a new tool for measuring student attitudes and beliefs about biology” at http://www.colorado.edu/sei/end_of_term.htm). Our further analysis of the results from EBIO1210 over the three years of our participation moreover suggests trends 1) for female students to shift even more strongly than male students to novice-like views irrespective of the gender of the instructor and, possibly, 2) for those students who start with more novice-like views in the first place (pre-class survey) to exhibit more pronounced shifts to even more novice-like views (post-class survey) compared to students who start with more expert-like views. We now propose to use the CLASS as well as other assessment tools to 1) continue to monitor the outcomes of our large EBIO classes over time as we institute a number of innovations designed to improve student learning and to 2) compare the outcome of the series of courses targeted by this proposal with the outcomes of the introductory course.

Finally, we will investigate how to best gauge improvements in students’ psychomotor skills. In this case we will focus on students’ ability to use technology for data collection and the application of appropriate analytical approaches for choosing among rival hypotheses. Various models exist for testing skills and we will investigate alternative approaches and choose a particular approach, or approaches, through a series of discussion in small working groups.

Another important tool for the assessment of teaching effectiveness is to employ independent evaluators (i.e. peer review). For this function, we will bring in someone with expertise in assessing teaching effectiveness to evaluate what we are trying to do and what we have done. Thus, part of our funding request reflects that this aspect of our proposal is a priority.

Participating Faculty and Incentives

The EBIO department met on 12/9/2010 for the purpose of discussing the proposed SEI grant and assessing the level of support for the grant. All faculty members who teach large enrollment courses were present. A motion for the department to endorse the goals of the SEI received *unanimous* support from the faculty. Additionally, there is heightened interest in improving our teaching in EBIO as evidenced by the very large and voluntary membership on the EBIO curriculum committee and the fact that we have full participation in this SEI proposal of all faculty members involved in all large-enrollment courses in EBIO with laboratory or recitation sections (Table 1).

One of the topics of our 12/9/2010 faculty meeting was how to generate incentives for participation in the proposed SEI-promoted revision of our teaching mission. It is clear that achieving our goals will require significant buy-in from faculty and there was some concern that investment in teaching will take away from the research productivity, especially of junior professors. As a department, we will therefore formally recognize the SEI activities of faculty on annual merit

evaluations. Additionally, we noted that the increased investment in teaching will be shouldered, to varying degrees, by the STFs. Finally, one direct incentive is that the SEI grant will provide some summer salary for working on course revision and assessment development; moreover, teaching buy-out will allow faculty to spend some time working on SEI-related issues.

Table 1. List of faculty who are committed to the EBIO SEI project. Those listed in bold will be the primary individuals for the SEI-funded transformative activities because we will focus on the three respective EBIO major core courses first.

Course	Course	Enrollment	Primary Faculty
General biology	EBIO 1210	1400	Dr. Barbara Demmig-Adams, Prof. Dr. William Adams, Prof. Dr. Sam Flaxman, Asst. Prof. Dr. Dan Medeiros, Asst. Prof.
General biology	EBIO 1220	1200	Dr. Brett Melbourne, Asst. Prof. Dr. Kendi Davies, Asst. Prof. Dr. Rebecca Safran, Asst. Prof. Dr. Pieter Johnson, Asst. Prof.
General biology lab	EBIO 1230	864	Dr. John Basey, Sen. Instr.
General biology lab	EBIO 1240	960	Dr. John Basey, Sen. Instr.
Ecology	EBIO 2040	300	Dr. William Bowman, Prof. Dr. Alex Cruz, Prof. Dr. Suzanne Nelson, Instr.
Genetics	EBIO 2070	150	Dr. Jeffry Mitton, Prof. Dr. David Stock, Assoc Prof.
Evolution	EBIO 3080	175	Dr. Patrik Nosil, Asst Prof. Dr. Andrew Martin, Prof.
Behavior	EBIO 3040	110	Dr. Michael Breed
Microbiology	EBIO 3400	140	Dr. Steve Schmidt, Prof. Dr. Noah Fierer, Asst. Prof.

Specific Plans for Science Teaching Fellows (STFs)

The STFs we plan to hire will have already earned their doctorates in biology and will have a strong interest and experience in science education. By having STFs explicitly associated with the proposed work, the coordination and integration across faculty members and courses will be greatly enhanced. To be clear, individual faculty members will have the primary responsibility for implementing learning goals and changes in practices in their own classes. To complement the work of faculty members, one role of the STFs will be to act as critical “nodes” in the departmental network. In this role, the STFs will 1) coordinate establishment of working groups around classes, learning goals, and assessments, 2) facilitate regular communication, 3) improve efficiency by making sure that different faculty members are working in synergy and not performing redundant or incompatible activities in the development of learning goals, and 4) develop sustainable, robust, web-based archives of learning goals, assessment tools, and other newly developed instruments for our classes. Finally, each STF will be specifically involved in the teaching of one of our core classes in each semester,.

STFs will be housed in offices within the labs of two of the Co-PIs (where desk space is available), facilitating daily interaction and a collegial rapport between faculty and STFs. In working on specific classes, STFs will receive guidance from the experienced faculty teaching those classes, and will also be mentored in the development of their own short modules of material for a given class. Finally, STFs will regularly (2-4 times per semester) present updates on their work at faculty meetings and informal “brown bag” presentations.

Anticipated Timeline

We have identified eight different components of the proposed SEI project that we have loosely scheduled for the next three years, including hiring STFs, formulating learning goals, developing assessments, implementing team teaching, providing summer support for curriculum development and data analysis, providing support for professional development (i.e. travel to professional meetings), and peer evaluation of the EBIO SEI program (Figure 4). Importantly, the formulation of learning goals will take place during the first year of the grant for all three targeted courses (with concurrent activities to facilitate integration of learning goals across the major). The development of assessments will commence after the learning goals have been established by consensus. Team-teaching will occur for each course in different years. It is likely that the transformation of our teaching will be a continuous and on-going process. Finally, funding for professional development and curriculum development will be restricted mostly to summer months.

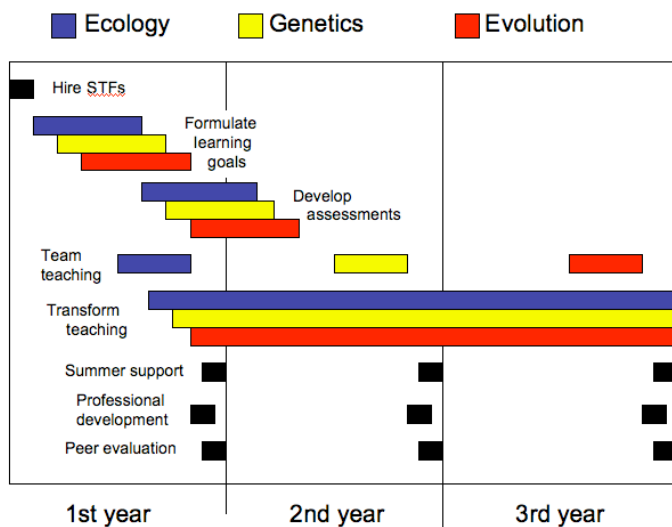


Figure 4. General timeline for specific tasks. The colors represent dedication to one of the three core courses. Note that there is overlap between the courses that will be important for integrating learning goals, assessment, and curriculum development across courses.

Anticipated Outcomes

The department of EBIO is excited by the prospect of advancing our teaching mission and transforming ourselves into more effective teachers. We anticipate that the SEI-funded activities will result in the following tangible outcomes:

- Establishment of learning goals that can serve as a guide for students and faculty members;
- Increased integration of the curriculum across courses;
- Increased participation of faculty members in education research;
- Increased teaching effectiveness;
- Development of standard assessments that align with learning goals;
- Establishment of an archive of clicker questions for each course;
- Establishment of course templates useful for new faculty;
- Increased recognition of teaching as an important component of an individual's merit;
- Increased dialog among faculty about the philosophy of why we teach what we teach.
- Increased recognition of advances in educational strategies.

Budget

Salaries	Year 1	Year 2	Year 3
STFs	98,000	101,753	105,651
Faculty buy-out	6,350	6,731	7,135
Summer salary	19,333	9,667	10,037
Evaluator	7,000	7,266	7,544
Total	130,683	125,417	130,367
Benefits			
STF (29.2%)	28,616	29,712	30,850
Faculty	6,425	4,132	4,290
Total	35,041	33,844	35,140
Meetings			
Travel	3,000	3,000	3,000
Total	168,225	161,761	168,006
Total for three years	499,492		

Budget Justification

Personnel—The bulk of funding is requested to support personnel, including support for two full time STFs, summer salary for faculty, some funding for peer-review evaluation of our program, and faculty buy-out of teaching in each year. As detailed above, the STFs will be integral and pivotally important members of the group charged with formulating and implementing learning goals, and assessing teaching effectiveness. These individuals will work closely with faculty across all targeted courses, and will be expected to advance an educational research agenda in the department. Summer salary will be available for a total of four faculty members (two in the first year and one each in subsequent years). Awards of summer salary support will be based on a competitive basis and interested faculty will submit proposals that describe their proposed work for the summer. A committee of peers will evaluate the summer salary proposals. An important aspect of the work is to receive peer review; thus, we request some funding to pay someone outside of the department to evaluate the project through a combination of reviewing learning goals, assessments, and curriculum and conducting interviews. Finally, we request funds for one semester teaching release once each year so that two faculty members can team teach and thereby learn from each other.

Travel—An important part of professional development is training; thus, funds will be available for travel to conferences and for publication. These funds will be awarded through a peer review process.

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