ACS Reform of Introductory Science courses for Non-Majors Course Mini-grants
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FINAL REPORT

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1. Original goals and objectives

Our original goal was to reinvent our first introductory biology course (Biology 1311) and the accompanying laboratory (Biology 1111) to improve the education of all of the students in the class (a mix of students who explicitly enroll as non-majors, those who become *de facto* non-majors over the course of the semester, and those who choose to continue on to further study in biology). Our vision was to teach biology not by content that is binned on the basis of traditional levels of analysis, but rather through what we hoped would be an accessible, novel, and stimulating format: *topic-based modules* that each integrate information across levels, from molecule to ecosystem. In this way we hoped to demonstrate by example that biological topics are best learned as integrated wholes, studied on multiple levels. In addition, we hoped that this new approach would allow us to engage students by presenting significant and timely topics in biology, and focus on teaching biology as an exemplar of science as a way of knowing (AAAS, 1990). Our approach in the accompanying laboratory course was to complement the lecture course by offering a small-group context and by focusing on the scientific process, emphasizing posing testable hypotheses, designing experiments, collecting and analyzing data, conducting library research, and producing professional research reports through a team-based process of writing, editing, and revising. We envisioned that these two courses would work together to teach biology as a discipline in which levels are connected and interrelated, a discipline that is valuable and relevant to our students' lives, and a discipline that is process-oriented and problem-solving. We believed that these goals, and our approach to accomplishing them, should in principle have a positive impact on the scientific literacy of our students and their valuation of science and its contributions to society

Much of the initial planning had taken place before the submission of this grant, including the choice of three modules for the lecture course (Evolution of Hemoglobin, Global Carbon Cycle, and Evolution of Sexual Reproduction). The period of the grant comprised the intensive course development phase in the summer before the first implementation of the new courses, as well as the implementation phase of the first semester these courses were taught. Our objectives for the lecture course (Biol 1311: Integrative Biology I) were to expand the syllabus of each module, choose appropriate readings, and design appropriate homework assignments and in-class

exercises, and then to carry out the first semester of this course. For the laboratory course (Biol 1111: Introductory Biology Laboratory), we had as a starting point our old laboratory course that had been offered only to non-majors. Our objectives for this lab course were to enhance the existing course to emphasize the scientific process. This entailed extensively revising and expanding the existing laboratory manual to clarify existing instructions, to locate and incorporate more in-class exercises to enhance understanding of material, to provide more explicit instruction on scientific writing, to choose appropriate research articles to give students experience with reading the scientific literature, and to develop an instructor's guide as a means for improving the communication amongst instructors teaching this course from year to year. We hired a student assistant who had recently served as a teaching assistant for this course to carry out much of this work, providing a very useful student's eye view of the course material.

Reference

AAAS, 1990, *The Liberal Art of Science: Agenda for Action,* Washington, DC.

2. Revised goals/objectives.

No revisions were made to our goals and objectives.

3. In what ways were the goals/objectives met?

Our planning objectives were met in that before the fall semester, we completed the syllabus, readings, and activities for Biology 1311 (see Appendix 1 for the syllabus), and completed a new laboratory manual for Biology 1111 (see Appendix 2 for a sample), and began an instructor's manual for this course (we envision this instructor's manual as being continually updated and thus is a work in progress). Our implementation objectives were met in that we successfully completed the first teaching of these courses, with a final enrollment of approximately 170 students in Biology 1311, and ten sections of on average 16 students each in Biology 1111.

Whether our broader goals were met is a harder question to answer, and we will be examining this question as a department for the next few years. In a broad sense, our main goal is a more successful introductory biology class than our previous introductory course. A successful course would be one that engages all students. This would mean that those students not continuing in biology leave the course with a solid understanding of the scientific process and of what comprises the overall domain of biology, as well as with enhanced knowledge of some specific biological principles and topics, and most importantly, with an appreciation for the beauty of biology and how it enhances our knowledge and experience about the world. For those students continuing in biology, in addition to carrying with them all of those lessons, we would also want them to finish the course even more energized and excited about biology than when they began, rather than seeing the course as a necessary hurdle to get to the "really interesting stuff" in the upper-division courses. Finally, this introductory course would ideally be so engaging that it convinces some students who had no plans to continue in biology to consider majoring or minoring in the subject, or at least taking more classes.

From the information we currently have, it is not immediately obvious that our new introductory courses (Biol 1311 & 1111) were more successful than our previous introductory courses in enhancing student engagement, but this may have to do with challenges presented by the course

structure (common to both the new courses and their predecessors) that go beyond curricular reform. The large size of the lecture course (at 170 students, it is by far the largest class at Trinity), and the disconnect that this class size tends to create between students and faculty, is one barrier to successful teaching, whatever the format or subject matter. Not surprisingly, students continue to be frustrated and dissatisfied with this large class size. Despite efforts to standardize the teaching of laboratories across sections by offering the instructor's guide and holding weekly preparatory sessions, differences across sections (or at least the student perception of such differences, in such matters as grading standards) are inevitable and this posed some challenges to the success of the laboratory class. In addition, since some laboratory instructors were not involved in the lecture course, there were some barriers to integrating material seamlessly between laboratory and lecture and vice-versa. All of these challenges can be addressed in subsequent years (see below).

More importantly to the theme of this grant is the issue of whether teaching *integrated* biology as an introductory course was more successful than our old approach, in which our first introductory course focused on the topics of evolution and genetics, leaving organismal and systems biology, and cellular and molecular biology, for later courses. Again, the jury is still out on this question. Our new approach clearly captured the imagination and engendered the excitement of *some* of our students, but many seemed to be confused by the format and what they perceived as "jumping around" too much from topic to topic. One clear challenge in this regard is that our approach precludes assigning readings in anything like the order of topics covered in the textbook, and this in itself tends to give some students the impression that we are skipping around in what seems to them to be a random fashion. While the topics we cover in each module are clearly integrated in the minds of the instructors, we need to do a better job of conveying that integration to the students so that we fully communicate how biology is an integrated discipline and why we see it as best to learn biology in this way. It is not surprising that our first implementation of this approach is less seamless than we would like, but we are committed to improving the integration of topics both within and between modules in the coming years as we continue to develop this course. Since the second course in the biology sequence (Biology 1312: Integrative Biology II) for students continuing in biology utilizes the same format, we are also working to improve the continuity between the two courses.

The laboratory class (Biol 1111) presents some challenges of its own. It builds on what was a fairly successful lab course previously offered only to non-majors. The format of this course, emphasizing student-generated projects of several weeks in duration, thus disappoints some of the more science-oriented students because they are repeating some of the same techniques (such as genetic crosses of *Drosophila*) that they may have learned in high school. Although the focus in our course is intended to be more on the process of hypothesis generation, literature review, collaboration within research teams, and producing more professional laboratory reports, if they concentrate more on what new techniques they are learning, they may be disappointed. At the other extreme, some of the non-major students seem to feel somewhat overwhelmed by the pace of the class and the amount of reading and outside work required, which have been increased from previous years. In addition, we faced many more serious problems with the functioning of research teams ("lab groups") than we had in previous years, most likely because most of the students in the new course now are first year students with little experience with working in groups (with the accompanying demands in time management, responsibility to others, and

negotiating interpersonal dynamics), whereas when the course was limited to non-majors, most of whom were at least sophomores, the groups functioned much better. One positive side to the challenge of group work in this course is that it presents a venue in which the more experienced non-majors can provide some leadership in their research teams, even though they may not be as comfortable with the course material.

The full achievement of some of our goals and objectives were impacted by a concurrent HHMI curricular reform grant that is aimed at enhancing the connections among introductory classes in biology, chemistry, math, and physics, the four disciplines required of all students preparing for careers in the health professions. This three-year grant (the second year of which overlapped with the ACS/Keck funded biology curricular reform initiative) entailed a two-year period in which three professors from biology were each paired up with a colleague in chemistry, math, or physics. One year the biology professor would sit in on the introductory class of the other discipline, and the following year the other professors would sit in on our introductory biology courses. Throughout this process, the faculty from various disciplines would discuss how to more seamlessly integrate these introductory courses, with the aim of making each of the non-biological courses more relevant to the student preparing for the health professions. This HHMI initiative impacted our concurrent and independent reform of the introductory biology curriculum in that it took some of the teaching hours of three biology faculty each semester away from directly teaching biology, thus necessitating that other biology faculty (as well as HHMI-funded teaching post-doctoral fellows) teach some the laboratory sections in both semesters (70% of the lab sections of Biol 1111 were taught by non-lecture faculty). The presence of laboratory instructors who were not directly involved in the lecture courses certainly had an effect on our ability to implement more lecture-laboratory integration. It also simply made our staffing, planning, and organization of the curricular reform logistically more challenging, with much of the work being taken up by junior faculty.

4. Describe the evaluation/assessment process used.

As described above, our vision for our new Integrative Biology course was founded on three principles: that biology is (1) a discipline in which levels are connected and interrelated, (2) a discipline that is valuable and relevant to our students' lives, and (3) a discipline that is process-oriented and problem-solving. Thus we planned to assess the success of our curricular reform primarily by measuring: (1) student understanding of the connections among the different levels of biology, (2) student attitudes toward science, and (3) student understanding of the dynamic nature of the scientific method. We have made progress on the first two measures, but have not yet devised an assessment that appropriately measures the third. For the second measure, we utilized the Science and Math Values Inventory (SaM-VI) developed by scientists at Drury University, testing the same students at the beginning and end of the fall semester. If we are successful we hope to see an increase in students' appreciation and valuation science at the end compared to the beginning. Because we were delayed in getting our tests to our colleagues at Drury, we do not yet have the results of the SAM-VI analysis for our course. We had also planned to compare these results with those from the two other non-major biology courses in our department (both of which do not have a laboratory component and are typically much smaller classes), but neither of them were offered this year, so that comparison will have to wait until next year. We are interested in the different experiences and outcomes for students who take a

laboratory course compared to non-laboratory courses we offer for non-science majors. We plan to utilize the SaM-VI assessment tool next year in both Biol 1311/1111 as well as the other two non-major courses we offer. As with all of our assessments, the best measure of our success would have been to have a baseline of results from our previous introductory biology course with which to compare our new curriculum, but unfortunately we do not have comparable assessment information from our earlier introductory course.

In order to measure improvements in student understanding of the connections among levels of biology, we developed diagnostic questions that test common student misconceptions about the topic of each module, to be given at the beginning and end of the module in Biol 1311 (following Ebert-May *et al.* 2003). We implemented such diagnostic questions for each of the three modules (see Appendix 3). The results suggest that our teaching approach did enhance student understanding of at least some of the concepts we hoped to convey. In addition, this process provided practice in designing and analyzing such diagnostic questions, practice which we can use to further refine this assessment measure in the future. As above, the best assessment of our new approach would have been to compare these results to those of our previous introductory course, but unfortunately, we do not have that information.

Although this does not concern the course explicitly covered by the grant (Biol 1311: Integrative Biology I), we also implemented two additional assessments as part of the second course in the biology sequence (Biol 1312: Integrative Biology II). All students (with a very few exceptions) who took this course had also taken Biol 1311, so some of these assessments may be relevant (with the caveat that the majority of students who completed both courses intend to continue on in biology). The first assessment was based on the approach of the SaM-VI, but explicitly addressing how students value different subject areas within Biology (see Appendix 4). We assessed student values using this inventory both on the first and last day of class of Biol 1312. By teaching *integrative* biology, we hoped to see an increase in student's appreciation for other areas of biology which may have been initially outside their area of interest. Our motivation for this assessment was that we have often heard students wanting to pursue a career in medicine complain about being forced to learn about evolution or ecology, or students interested in environmental science not understanding why they need to know anything about molecular or cellular biology. One of our goals of the new curriculum is to demonstrate to these students the relevance of all areas of biology to whatever their particular area of interest might be. Unfortunately, the results of this assessment do not seem to indicate that student appreciation of all areas of biology increased, since we saw an overall decrease in the average level of interest in almost all subject areas. Some of the low scores on the inventory in the post-course test may simply be a result of giving the test on the last day of class, when students were undoubtedly feeling stressed by the upcoming final exam and burned out at the end of the semester. We would recommend giving such a post-test at least a week earlier in the future. In addition, it might be helpful for students to have their previous scorings available, so that they can explicitly assess for themselves how their interest level in a particular subject matter may have changed over the course of the semester. We are still analyzing this data, but feel that this may be a useful additional assessment tool and will possibly utilize a revised version again next year, for both semesters of Integrative Biology.

The second assessment tool we utilized in Biol 1312 was an online survey using the Survey Monkey tool (www.surveymonkey.com). We compiled a list of all students who had been enrolled at any time in either Biol 1311 or 1312, which totaled 182 students. All of these students were emailed a request to participate in the survey in the final weeks of classes in the spring semester, with two follow-up emails, and the survey remained open for approximately 3 weeks (until the end of finals). By the close of the survey, 92 students had responded (a 50.5% response rate), representing both students who had taken only the first semester, or both semesters, or even only part of the first semester. Hence the respondents are a mix of our traditional "non-majors," taking Biol 1311 to fulfill their distribution (Trinity's Common Curriculum) requirement, those who became *de facto* non-majors by deciding not to continue in biology, as well as students planning to continue on to major in biology. The survey contained both multiple-choice and free-response questions, and both indicated that the Integrative Biology courses, with their accompanying labs, were experienced very differently by different students (see Appendix 5). Unfortunately, the perhaps most significant result is that the course changed the interest of the majority of students to make them *less* interested in biology, which is the exact opposite of the effect we hope to have. The free-response answers revealed that the reasons for student dissatisfaction could be grouped into a few main categories: the size of the course and resultant perceived lack of interaction with the professors; the difficulty of the material, especially the difficulty of the tests, and what they perceived to be an assumption on the part of the faculty of too much prior knowledge of chemistry and biology; and what some students called "skipping around" and others "disorganization." Some of what they perceived as a lack of organization was probably due to the fact that the courses were being taught for the first time, and so this can be ameliorated in coming years, but some students also just had a hard time adjusting to the nature of the modular approach. This is an area in which we can improve by making more explicit the connections we see between levels of organization within modules, and between the different modules themselves. In addition, some of the student experience of disjointedness seems to stem from the fact that they were taught by six different professors over the course of two semesters, since each module is taught by a different professor. On the other hand, other students commented that they really enjoyed the opportunity to get to know several biology professors, so there seem to be both positive and negative pedagogical effects of our team-teaching approach. Since our modular approach necessitates this kind of team teaching, we need to work on making the transition between teaching (and testing) styles easier for students and highlighting for them the benefits of the team-taught approach. We took two different approaches to handling the multi-instructor challenge in the two Integrative Biology courses. In Biol 1311, we planned to have one faculty member serve as the principal writer of all exams to try to limit the multiple instructor effect. This plan worked well for the first test but there were issues of time constraints on the second two exams. In Biol 1312, the method we devised to prepare students for the different testing styles was to provide non-graded problem sets every week written by the instructor of the module, as well as administering two quizzes written by the instructor. Since the quizzes were each worth much less than each exam, we reasoned this might be a low-risk way for students to gain experience with the different testing styles. Both approaches have merit, and we need to work on implementing each of these (as well as others) in future years to minimize the negative effects of the team-taught approach on student learning.

Reference

Ebert-May, D., Batzli, J. and Lim, H. 2003. Disciplinary research strategies for assessment of learning. *Bioscience* 53:1221-1228.

5. "Lessons learned."

In order for our goals for student engagement to be fulfilled, we have realized that in addition to our curricular reforms, changes need to be made to our introductory course structure. Starting in Fall 2006 we will teach Biol 1311 in two sections to reduce the size of the lectures (estimated starting enrollment of approximately 90 students each) and allow us to use a newly built classroom with state-of-the-art technology. We are also working on solutions to improve the lecture-lab integration. One approach we are considering is to reduce the number of sections of the lab course (Biol 1111) by having each section meet every other week, thus allowing more sections to be taught by faculty involved in the lecture course, which should enhance lecture-laboratory integration. In retrospect, each of these changes might have been effectively implemented in our first semester teaching these courses. In hindsight, it might have made the most sense to teach a pilot run of this course on a smaller group of students to work out the kinks first, so that the challenges of teaching with this new approach were not confounded by the difficulties of teaching a large lecture course. Unfortunately, at our current staffing levels, we do not have sufficient teaching faculty to make this feasible, but it might be recommended to other institutions who might want to model our integrative approach. Finally, in retrospect it was probably too much to take on as a department to simultaneously revise our introductory curriculum to such an extent while we were also involved in the HHMI-funded revision of all introductory science curricula. The demands that these simultaneous reform efforts placed on faculty were substantial, especially considering that the majority of the introductory teaching in our department is done by junior faculty.

A more difficult issue is whether the explicitly non-major students should be taught separately from those students who plan to continue on in biology (these include many students planning a career in medicine or allied health professions, since they are required to take at least four biology courses). We have not taught these students separately in the past for several reasons. One of these reasons is simply logistic, in that we have had a limited number of faculty hours available. In addition, however, we had a solid pedagogical motivation: all of the innovations we felt would best teach scientific literacy to non-majors would also provide potential majors with a solid foundation on which to build in advanced biology classes. Finally, the reality is that many students enter our university initially planning to pursue a health science-related course of study, only to discover that their interests and motivations lie elsewhere. Thus any introductory course, including one intended only for potential majors, ends up educating many students who become *de facto* non-majors by the end of the semester. All of these reasons together provide a solid motivation for continuing to teach our non-majors together with potential majors. However, we have discovered this year a difference between students who have had a solid background of previous coursework in biology and chemistry from high school and those who have not. These groups do not break down completely along the major/non-major categories, but non-majors do tend to be those students who feel the least comfortable with biology and science in general than those students planning to continue in biology. Many students commented in our anonymous student survey that they felt that our teaching of the material assumed a lot of prior knowledge. For this reason alone (along with the added benefit of further reducing class size), we are considering offering a separate course for non-majors (with an accompanying laboratory) sometime in the future (when faculty staffing levels permit). We would only do so if we can ensure that the non-majors course would not be "dumbed-down" in any way, and if we can work

out a mechanism by which a student in the non-majors course who was so taken with biology that he or she wanted to continue to take more classes, was able to do so relatively easily. We do feel that our approach in teaching *integrative* biology, using topic-based modules, would translate well into an explicitly non-majors course. We have discussed possibly expanding one or two modules into a semester-long non-majors course. We see the advantages of our integrative approach for non-majors as demonstrating the immediacy and relevance of biological knowledge by focusing on a current "hot topic," and also providing a breadth of biological concepts at multiple levels that might be difficult to accomplish in a traditional course limited to a single level of biological analysis.

6. How have you shared the results with ACS colleagues and beyond ACS?

We presented a talk based on our initial experiences with class planning at the ACS *Science Education Reform Workshop* at Furman in September, 2005. We presented an update of this talk at a recent PKAL Leadership Initiative Seminar on *Building Programs that Ensure the Success of All Students* held at Trinity in February, 2006. We will also present our experiences in a talk at the upcoming HHMI conference on *Interdisciplinary Science & Mathematics*, open to science faculty of all ACS member schools, to be held Trinity this October. After more evaluation and assessment, and more experience gained from teaching this course in subsequent years, we plan to write up our experiences for a publication such as the *Journal of College Teaching* or *The American Biology Teacher*.

7. What are the next steps (follow-up) in your project?

We continue to develop and revise both Biol 1311: Integrative Biology I and Biol 1111: Introductory Biology Laboratory. As discussed above, we are already implementing some changes (such as teaching smaller lecture sections), and we will continue to assess our progress and adjust our approach as seems warranted by the results of ongoing assessment. One ongoing challenge in our department is the lack of a full-time laboratory coordinator, so the addition of such a position would enhance the flexibility of our teaching time so that we might eventually be able to develop a separate non-majors course based on our integrative approach. A laboratory coordinator would also enhance our ability to make ongoing improvements to the laboratory course by providing a continuity between years that currently does not exist.

8. A complete financial statement, showing original budget (the breakdown of the amount awarded) and expenditures.

Please see Appendix 6.

9. *We grant permission for ACS to post our original proposal and this final report on the ACS Science Reform website.*