

ACS Science Reform Course Mini-Grants
2005-06

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Project Title: INTRODUCTORY SCIENCE COURSE REFORM:
 INTEGRATIVE BIOLOGY AT TRINITY UNIVERSITY

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Summary

The Biology Department at Trinity University is charged with the responsibility to teach both majors and non-majors in our introductory biology course. Our goal in this current proposal is to reinvent our introductory course, along with its accompanying laboratory, to improve the education of students from all majors, and to address the concept versus content challenge facing introductory biology curricula today. Our vision is to teach both concepts and content through *issue-based modules* that integrate across all biological levels. In these new courses, we will 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 believe that these goals, and our approach to accomplishing them, will have a positive impact on the scientific literacy of our students and their valuation of science and its contributions to society.

As a department, over the past two years, we have completed the hard work of solidifying a unified departmental vision of pedagogical goals for all of our students: to instill in them an

appreciation for the unique approach to knowledge offered by science, and to provide them with the skills necessary to deal with the explosion of scientific knowledge that will continue to affect all of our lives. We will continue our tradition of teaching our introductory course to both non-majors and majors, as we recognize that all of the innovations that will teach scientific literacy to non-majors will also provide an excellent foundation for potential majors. We have set out the framework for the new courses Integrative Biology (Biol 1311), and Introductory Biology Laboratory (Biol 1111). We are therefore requesting funds for an intensive period of course design and implementation from May to December 2005 in order to make our vision a reality.

Goals and objectives

Our goal is to reinvent our main introductory biology course and the accompanying laboratory so that we can best educate all students. We will do this by presenting biological issues as integrative wholes, studied on multiple levels, and by giving students direct experience of science as an investigative process. We have founded our vision for our new courses on the following three assertions.

We believe biology is:

- *an integrated discipline in which the connections and interrelationships between levels are critical to understanding unifying principles;*
- *valuable and relevant to our student, in understanding themselves as biological beings, in appreciating the natural world and their place in it, and in recognizing the implications of biology in matters of policy and society;*
- *a dynamic, process-oriented discipline focused on solving problems through observation, experimentation, and analysis, rather than a collection of static facts.*

Our vision is to teach biology not by content that is binned on the basis of traditional levels of analysis, but rather through *issue-based modules* that are each integrated across all biological levels, from molecule to ecosystem. This approach will allow us to engage students by presenting some of the most significant and timely topics in biology in an accessible, novel, and stimulating format. By reorganizing our course in this way, we will also focus on teaching

biology as an exemplar of science as a way of knowing (AAAS, 1990). The accompanying laboratory course will complement the lecture course with its small-group context and focus on the scientific process, rather than a series of techniques free of investigative context. The emphasis will be on 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. These two courses will work together to provide students with an integrated view of the current state of knowledge in the biological sciences and the means by which this knowledge was acquired.

Background and significance

In attempting to provide undergraduates with a solid introduction to biology, faculty are faced with the overwhelming explosion of research in biology at all levels of analysis. Faculty most often choose to divide this information into semester-long chunks, with levels of analysis providing the divisions. Thus, the biggest variation between institutions becomes whether they choose to begin at the molecular level and work their way up, or at the ecosystem level and work their way down. At Trinity we have traditionally taught introductory biology as a course on evolution, deemed to be the logical starting point given its position as the central organizing principle in biology. Students who continued in biology then worked their way to organisms and systems in the second course, and finally to cells and molecules in the third course. One flaw we noticed by tracking students who continued in biology was that these students continued to compartmentalize biology based on the subject matter of these three classes, often failing to see the relevance of evolution to molecular biology or the relevance of biochemistry to ecology. This problem has been decried for the learning of science in general (Stith 1999) and is equally debilitating to students learning biology.

When we set out last year to reexamine our curriculum for the first time in 17 years, we first defined the outcomes we wanted from *all* students in a college-level introduction to biology. Foremost among the goals we identified was an understanding of biological systems and processes *across* the traditional levels of analysis. This goal is a logical extension of the philosophy of teaching science in the same way it is practiced (Handlesman *et al.* 2004). We thus set out to completely reinvent our introduction to biology as one that uses issue-based modules to achieve the following: teach basic scientific method and biological principles, present material of relevance to today's society, and illustrate how levels of analysis are integrated in the understanding of complex biological issues.

We had traditionally taught our introductory course on evolution to both majors and non-majors. In our curricular reform process, we chose to continue this pattern and not create separate courses for majors and non-majors. 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. Moreover, the reality is that many students enter our university initially planning to pursue a medical (or other life science-related) course of study, only to discover that their interests and motivations lie elsewhere. Our introductory course therefore includes students who (1) explicitly enroll as non-majors as part of the requirements for the university's Common Curriculum, (2) become *de facto* non-majors over the course of the semester, or (3) choose to continue on to further study in biology. The latter is the smallest fraction of the class; our latest data indicate that approximately 15 % of the students enrolled in our introductory course complete a major in biology. We thus recognize that we have *one* opportunity to instill in all of these students an appreciation for the unique approach to knowledge offered by science, and *one* opportunity to provide them with the skills necessary to

deal with the explosion of scientific knowledge that will continue to affect all of our lives. Our curricular reform discussions consequently centered on what we most wanted *all* students to take away from their initial (and perhaps final) exposure to the science of biology. We identified the central three assertions of biology detailed above, and we recognized that implementing issue-based modules was the mode of teaching that would best communicate our vision to students.

Context of course in curriculum & impact on the institution

Trinity University mandates general education requirements (The Common Curriculum) for all students, to provide “a basis for understanding the varied domains of human knowledge and experience” (Trinity University Courses of Study Bulletin 2004-2005). The Common Curriculum prescribes courses from each of five “Understandings” that span the breadth of human intellectual endeavor, including “Understanding Natural Science and Technology.” Students must take two courses in this Understanding, totaling at least 6 hours, and one of these must fall into the category of “Using Scientific Methods,” which requires active involvement in using scientific methods to study natural phenomena (what we normally call a lab course).

The course we are developing, Integrative Biology (Biology 1311), will be the first course in the biology sequence, as well as fulfilling the Natural Science and Technology requirement of the Common Curriculum. Introductory Biology Laboratory (Biology 1111) will be required of all Biology majors, and will also fulfill the “Using Scientific Methods” requirement. Students may take either 1311 alone or in conjunction with the laboratory, but 1311 is a co-requisite of the laboratory, ensuring a common context and preparation of all students in the laboratory course.

We anticipate an enrollment of approximately 200 students per year in Biology 1311, with perhaps a slightly smaller number (about 180) in the 1111 laboratory. Last year's enrollment in our former course (Biology 1318) was 170, but we expect enrollment to increase because we will no longer allow AP credit to substitute for this course. Enrolling almost eight percent of the student body per year, there is no other single course at our university of comparable size.

Prior activities related to proposal

During the 2003-2004 academic year, as part of a university-wide effort, the Biology Department was charged with re-examining our curriculum, including our contributions to the Common Curriculum. We chose to focus on our introductory course, understanding that we would only be free to consider changes in our upper-division offerings if we first dealt with the unsolved challenges of our introductory course. It was a propitious time for a reexamination given that almost one-half of our faculty joined the department within the last four years.

We met twice weekly over both the fall and spring semester in an intensive effort to examine both what we have traditionally done well and areas where we would like to improve. After much deliberation over the specific topics and skills we wanted student to master, we began to consider the radical rethinking of our mode of teaching, which eventually solidified in the issue-based module approach.

Detailed project plan

The course descriptions for the new courses, Biology 1311 and Biology 1111, and our tentative schedules for each course, are included as Appendices 1, 2, and 3. Biology 1111 is a modified version of an existing course (Biology 1118) that will be considerably expanded in scope and aims as well as in audience, as it had previously been taught only to non-majors. Biology 1311 is a completely new course.

As described above, we have already expended considerable time and effort into designing these courses. We have articulated our vision for the courses, and we have now received approval for these curricular changes from our curriculum council. What remains for us to do for the lecture course (Biol 1311) is to develop a detailed syllabus, identify appropriate supplementary readings, and design appropriate diagnostic problem sets to be used as assessment

tools, as well as in-class and take home exercises and assignments. For Biol 1111, we need to design new laboratory exercises, refine existing exercises, clarify and elaborate our statistical procedures and instructions for writing reports, identify appropriate research articles to serve as background reading and models for reporting scientific data, implement new equipment and software, and organize the laboratory space to prepare for 10 laboratories/week in only two rooms.

These new courses represent a major restructuring of our curriculum. Our aim is to accomplish these objectives through the intensive efforts of four faculty and one student assistant during summer 2005. Funding from ACS will provide support during this intensive period of course design and implementation at this crucial juncture and will ensure that we are well prepared to implement the new courses for the first time in the Fall 2005 semester, so that we can fully realize our vision for these innovative new courses.

Projected timetable

The timetable below details what we have already accomplished and what we plan to accomplish during the period covered by this grant.

Fall 2003 - Spring 2004: Regular departmental faculty meetings to assess current Biology curriculum & consider changes (last changed 17 years ago). First envisioned switching from content-binned courses to integrative, module-based courses and sketched out several possible modules.

Fall 2004: Along with two new faculty who joined the department, continued faculty meetings to write course descriptions, sample syllabi, and rationale for our curricular changes for review by the University Curriculum Council. Proposed changes pass the UCC. The Department Chair (Ribble) attended the ACS Science Education Reform workshop at Millsaps College to gather information relevant to our goals.

Spring 2005: Chose textbook (Scott Freeman's Biological Science, second edition), submitted requests for ACS funding, identified Kyle Brillante as student assistant for summer work.

Summer 2005: *Biology 1311*: write detailed syllabi, lesson plans, choose supplemental readings, plan activities (Livingstone, Lyons & Shinkle). *Biology 1111*: re-write laboratory manual, design new activities, order and test equipment, choose supplemental readings (Pope, along with student assistant Brillante).

Fall 2005: Implementation of Biology 1311 and 1111, ongoing assessment.

Spring 2005: Final reports on course outcomes completed and reported to ACS at appropriate conferences, and at Trinity HHMI symposium. Summary reported on Biology Department website.

Evidence of institutional support

This grant is supported by the Chair of the Biology Department and the Vice President of Academic Affairs at Trinity University, Dr. Michael Fischer (see attached letter of support). The University will be purchasing six new computers for our Biol 1111 laboratory course. The University will also provide our student assistant with university housing for the summer if this grant is funded. The Department of Biology will continue to pay the costs for all expendable materials for the laboratory. In 2004 the Biology Department spent \$1145 on Fast-Plant supplies, *Drosophila* supplies, and access to the Fly-Lab web materials. In the coming year we will be accommodating about three times as many students, so our expenses will likely triple. These future demands on the Biology budget necessitate that we secure funds for equipment and software that will be used for years to come.

Evaluation, Dissemination, and Continued Support

In our evaluations, we will be concerned primarily with 1) assessing student attitudes toward science, 2) assessing student understanding of the dynamic nature of the scientific method and 3) assessing student understanding of the connections among the different levels of biology. We will assess our progress in convincing students of the value of biology in their life through the Science and Math Values Inventory (SaM-VI) developed by scientists at Drury University. We have contacted Dr. Bruce Callen and he has agreed to include us in his inventories at the start and end of the course. If we are successful we hope to see an increase in students' appreciation and valuation science at the end compared to the beginning. We will compare these results with other non-major science courses taught in Biology that do not have a laboratory component and are typically smaller (15-25 students per course). 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.

In order to assess student understanding of the dynamic nature of the scientific method and the connections among the different levels of biology, we will develop a series of diagnostic

problem sets designed to test student misconceptions (Ebert-May et al. 2003). These problem sets will be developed based on the principles and examples provided by Diane Ebert-May and her colleagues (see www.first2.org). We believe our module-based approach and explicit emphasis on integration across levels of biology (cell, organism, and population) will assist students to make the connections in each module. These problem sets will be administered at the beginning and conclusion of each module and will be graded using a rubric that assesses the extent of students' understanding of concepts.

Every faculty member involved in this course will use Trinity's standardized teaching evaluations which give students the opportunity to provide written evaluative assessment of the curriculum. We will also have the opportunity during Fall of 2006 to obtain an "external review" from our colleagues in chemistry, physics, and math. As part of a Howard Hughes Medical Institute (HHMI) grant, we will be trying to make linkages between other disciplines and biology that are compelling and apparent to our students. This process will begin with faculty members from other departments sitting in on our courses and making specific curricular suggestions to include chemistry, math, and physics in our biology courses.

We plan on sharing our experiences, including the assessment procedures and diagnostic problems, through the Biology Department website and a website for the HHMI. Trinity will also be hosting two "Interdisciplinary Science Curriculum" conferences as part of our HHMI grant during the next two years. A representative from each ACS campus will be invited to Trinity for these conferences, and we plan to use these venues to share with others our experiences with this course. One of us (Ribble) recently attended the Science Education Reform Workshop held at Millsaps in November 2004, and we would plan to attend any similar

workshops to present our progress and assessment results. Lastly, we plan to write up our experiences for a publication such as the *Journal of College Teaching*.

References

- AAAS, 1990, *The Liberal Art of Science: Agenda for Action*, Washington, DC.
- Ebert-May, D., Batzli, J. and Lim, H. 2003. Disciplinary research strategies for assessment of learning. *Bioscience* 53:1221-1228.
- Handelsman, J. *et al.* 2004. Education: Scientific teaching. *Science* 304, 521–522.
- Stith, J.H. 1999. Random thoughts on interdisciplinary science. *Proceedings of the Interdisciplinary Workshop on Core Mathematics: Considering Change in the First Two Years of Undergraduate Mathematics*, West Point, NY.

Appendix 1: Course descriptions as they will appear in the 2005-2006 Trinity University Courses of Study Bulletin

BIOL 1311 Integrative Biology I

This course is designed to introduce students to the wide range of knowledge in the biological sciences and with the methods that have built this knowledge base. The course is organized around a series of topic-based modules, each of which will integrate modern biological approaches at the cellular, organismal, and population levels. Modules for this first semester course will include global biology change, sexual reproduction, the evolution of hemoglobin, or other contemporary topics. Grades for this course will be determined by exams on each module, a comprehensive final exam, and take home exercises and assignments. This course is appropriate for non-science majors and will meet 3 class hours a week for one semester in the fall only.

BIOL 1111 Introductory Biology Laboratory

This is an introductory laboratory course that provides an understanding of the scientific methods used to investigate biological questions and how the results of these studies are communicated. The semester is divided into three investigative modules in which student groups learn a technique, conduct an experiment or study, and write their results in the form of a scientific paper. Each group will also make a presentation on the biodiversity of particular groups of organisms. This laboratory course is appropriate for both non-science majors and science majors. Grades are determined from the reports and presentations. 3 laboratory hours a week for one semester in the fall only. Biology 1311 must be taken concurrently.

Appendix 2 (next page): Tentative Schedule & Syllabus for Biology 1311

**Proposed Schedule/Syllabus
Fall 2005**

Each module will be team taught, with an exam over the topic at its conclusion. A comprehensive final exam over all modules will be administered during finals. Various take-home, blackboard assignments will complement lecture materials.

**Textbook: Freeman, S. 2005. *Biological Science*, 2nd edition. Prentice Hall.
Course Pack of supplemental readings to be determined.**

Weeks 1-4

Module	Cellular	Organismal	Population
Sexual reproduction	Meiosis Repair mechanisms Hormonal Mechanisms at cellular level Ovulation Spermatogenesis	Endocrinology at systems level Birth: smooth muscle contraction	Principles of natural selection The paradox of the evolution of sex R vs. K-selection Eusociality Asexuality

Weeks 5 – 9

Module	Cellular	Organismal	Population
Adaptive evolution of hemoglobin	Central dogma: DNA structure, transcription, translation Protein structure: primary, secondary, tertiary, quaternary Heme and globin Reversible oxygen/CO ₂ binding by hemoglobin	Essential role of oxygen in respiration Circulation Alternative reproductive (circulation?) strategies The oxygen hurdle to internal growth of the embryo/fetus Self/non-self recognition The placental barrier	Origin of globins Diversification of globins in mammals -- duplication, mutation, differential regulation Test of adaptive evolution in globin genes Putting it all together-expression profiles of different globin loci during development (<i>in utero</i> through postpartum)

Weeks 10 – 13/14

Module	Cellular	Organismal	Population
Global change biology	Cellular thermodynamics Kinetics Enzyme function Photosynthesis & respiration	Autoecology of temperature effects on individuals Morphology Metabolism Physiological Ecology Decomposition	Competition and population ecology Community/ecosystem functioning Invasive species biology Global Nutrient Cycles (C, N, S, P)

Appendix 3: Tentative Schedule for Biology 1111

Biology 1111 Laboratory Schedule - Fall 2005

Week	Unit	
1	I	Introduction to laboratory, procedures, and computers; Introduction to fast plants and hypothesis generation.
2	I	Set up experiments with fast plants; library exercise on literature searching.
3	I	Reading and writing a scientific paper; introduction to statistical analysis.
4	I	Measurements, data analysis, and write-up of fast plant experiments.
5	II	Introduction to fruit fly genetics.
6	II	Design genetics investigation; Biodiversity project proposal due.
7	II	Cross-over and recombination.
8	II	Statistical analysis of phenotypic ratios in genetics.
9	II	Analysis and write-up of genetics experiments.
10	III	Introduction to phylogenetics and software to analyze and build trees.
11	III	Design phylogenetics study; Biodiversity project progress report due.
12	III	Analysis and write-up of phylogenetics study.
13		Thanksgiving.
14		Biodiversity presentations.