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Biology and Society: Educating for the Future

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Background

Our Biology and Society program grew out of the common interests and goals of both life science faculty members and undergraduate students. Both groups saw this type of scholarship as an important way to prepare for careers in the 21st century in which the societal implication of biological research will become increasingly significant and complex. Modern science requires the ability to cross disciplinary boundaries and to work together in teams. The Crosscutting programs at the National Science Foundation, for example, are predicated on this assumption. The most successful and most innovative scientists are those with not only training in more than one discipline, but also commitment to breaking down barriers and bridging across boundaries. Not surprisingly these views were especially common among students and faculty with interests in biomedicine and conservation biology.

On the faculty side, both research-active biologists and scholars from other disciplines—especially history and philosophy—were increasingly interested in examining, within their research and teaching, the relationship between science and society from multiple and new perspectives. In part, this was a natural outgrowth of national trends that are reflected in our efforts to expand our approaches to undergraduate biology education to make it more inclusive and attractive to a diverse metropolitan student population. Making biology explicitly relevant to and clearly set in a broader societal context was a key part of this effort for which we successfully sought funding from the Howard Hughes Medical Institute (HHMI). These funds helped us implement inquiry-based

pedagogy focused on science as a process, revise our curriculum, renovate lab classrooms, and give students opportunities to engage in research.

At the same time, students were increasingly active in seeking opportunities to study the history and philosophy of biology. Around 1990, our Honors College was rapidly growing and improving its programs and so attracting many outstanding students. These students in particular were eager to study a diversity of subjects and to engage the problems of the world. A surprising number were biology majors (biology department majors constitute the largest percentage of honors students at ASU), and many of these on the pre-medical track, but some were often pursuing another major or minor as well and anxious for chances to exercise their broad interests.

So, we began the process of developing a program that explicitly presented and discussed science and its products as they are embedded in a social and political world. An agreement between the College of Liberal Arts and Sciences dean's office, the biology department chair, and the founding director (Jane Maienschein) established and funded the program in the fall of 1995. The first year we set up an office (with renovation funds), hired an administrative assistant, established an advisory committee, and employed a graduate assistant to survey the structure of similar programs in the U.S. and elsewhere. We found few models to follow, although Cornell's Biology and Society, Stanford's Human Biology, and Harvard's History and Science programs all offered inspiration. Transferring the experiences of these programs to a very large public university proved challenging.

The result was a comprehensive interdisciplinary academic program, the main focus of which is a broadly interdisciplinary major, housed within the biology department. The program also has extracurricular elements including an emphasis on attending seminars and conferences. Planning for the major began in the early 90s and it was finally approved and available to students in 1996. Since

then, enrollment in the undergraduate major has risen steadily, we now have over 50 students involved with the program, and have added faculty with explicit commitments to the program.

The Major

The major is formally considered an emphasis within Biology, which means that students graduate with a Biology degree and an emphasis in Biology and Society (similar to tracks or concentrations in other programs). The core requirements parallel those of the standard Biology major, which also includes considerable flexibility after the initial basic courses. The major consists of 44 semester credit hours of core courses, upper division life science electives, physical science electives, and math proficiency courses (Table 1). Additionally, students take 12 semester hours of *Interface Courses* (described below). Students also satisfy both university general studies (UGS) and College of Liberal Arts and Sciences (CLAS) distribution requirements to complete the 120 credit hours required for the degree.

Table 1. Curriculum for the Biology and Society major.

hrs = semester hours, UD = upper division (junior- or senior-level courses)

Required courses:

- Two semesters of general biology
 - A 3 hr UD course called *Biology and Society*
 - A 3 hr UD course in either ecology or evolution
 - A 4 hr UD course in genetics
 - A 3 hr UD course entitled *Research Colloquium in Biology and Society*
 - At least 3 hrs of independent research
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Additional coursework includes:

- 12 hrs of Interface courses with at least one course from each of three areas of: Ethics, History and Philosophy of Science, and Science in Contemporary Society
 - 12 hrs of UD electives in life sciences
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Core and elective coursework

As previously mentioned, the core courses and upper-division electives, which combined total 31 semester credit hours, provide a solid background in biology. The additional credits in physical sciences complete the strong scientific foundation of the degree program. There is a particular focus on research provided through an upper-division course that explores the research enterprise (*Research Colloquium*) and required research or independent study credits. Requiring independent research of each student can be challenging for a large department at a university the size of ASU. At the very least, student research requires the commitment of time and sometimes funds from a faculty mentor. However, the benefits for the students are immeasurable. We are currently working to secure additional funding for undergraduate research and to recognize faculty efforts in mentoring undergraduate students. These issues will become even more pressing as students are attracted to the major.

Interface courses

The Interface courses are the least obvious, but the principles are straightforward. They build from an approved set of courses across a number of departments and disciplines that develop skills for thinking about science in society. Each course is interdisciplinary by design, crossing the boundaries of life sciences and humanities or social and behavioral sciences. Examples include *Environmental Ethics* (Philosophy,

PHI 310), *History of Medicine* (History & Philosophy of Science, HPS 331), and *The Darwinian Revolution* (Humanities, HUM 372). While we provide a list of automatically approved courses in any given semester, students can propose others. The objective is to allow students flexibility while emphasizing analytical rigor and skill development. Interface courses can work in the student's program of study by fulfilling nearly half of the UGS or CLAS requirements in humanities and social and behavioral sciences. Indeed, one very positive result of the development of this program is that students from various life science degree programs – ASU has nine such programs – are taking these Interface courses to fulfill their UGS and CLAS requirements. For example, only 23% of the students enrolled in the Biology and Society course last spring were *Biology and Society* majors. In addition, many of the Interface courses are also cross-listed with Biology Department numbers, e.g., *History of Biology* is offered as BIO 316 or HPS 330, so students have flexibility with regard to where they use the course in their program. We have also designed the major so that the coursework and research projects can be carefully tailored to each student's needs and objectives. We guide students through individualized advising to work from their objectives to gain the range of skills and perspectives that will serve them well in the future. While the benefit of such individual attention to students is large, it produces a faculty and staff workload that must be considered when designing this type of degree program. Currently we are considering the development of a peer-advising program and are redesigning our website to alleviate some of this workload.

Interdisciplinary Courses, Materials and Methods

The core courses in our program are two innovative interdisciplinary courses, the *Biology and Society* course and the *Research Colloquium*. The overall goal of this core sequence is to provide experiences that stimulate students not only to deepen their understanding of contemporary biology but also

to think critically about its history, philosophical underpinnings, and social implications. Both have evolved as we learn from our past experiences how best to achieve these goals.

Biology and Society was initially team-taught by Jane Maienschein, a philosopher/ biologist, and by James Strick, a historian of science with a microbiology background. The course offered sections on endangered species, bacteriology, medical policy, and other contemporary issues, that served as cases to illustrate not only basic biological principles and phenomena, but also how scholars from other disciplines such as history or philosophy would study these issues. Most recently, Stephen Pyne, an international expert on the cultural and social history of fire and fire management, and Jane Maienschein team-taught the course, and introduced new topics such as fire, evolving biogeographical distributions in historical context, and developmental biology issues. We are developing a rich library of topics that can be used in this course to illustrate the interactions between biology and society.

From an exclusively lecture format, we have increasingly employed break-out groups and small-group discussion during the class periods to actively engage students in grappling with the issues at hand. We employ senior undergraduate students as teaching assistants (TAs) to lead these discussions, but as the class size has grown from around 30 to 75, we need to find additional techniques to stimulate student involvement. The faculty and TAs will be working with the Center for Learning and Teaching Excellence to acquire skills for active and collaborative teaching techniques in order to facilitate learning in large classes.

Reading assignments come from a packet of primary and secondary sources that present historical, philosophical, and ethical perspectives on current events and professional conduct in the sciences and other disciplines. We have found it effective to include both historical and current events, drawing from local newspapers and introducing students to such national outlets as the *New York Times* or *Washington Post*, and professional journals. Undergraduates often do not have much sense of what it means to be a professional, and how

that differs across departmental and disciplinary cultures, so this course introduces that awareness as well. We read a set of assignments, and then discuss what kind of sources they represent, as well as what they say.

The *Research Colloquium* course in our core sequences is a more formal exposure to the scientific process in contemporary biology and its societal implications. This course has been taught by Ronald Rutowski, an animal behaviorist with a broad liberal arts perspective. The course meets once a week and centers on our weekly biology department seminar. Students come to each class having read an article written by the seminar speaker. The students spend the first hour discussing the intent, purpose, and results reported in the article and then attend the seminar in the second hour. We meet again for an hour after seminar, often with the speaker, to discuss the content and presentation of the material. Rutowski also guides the discussion to broader issues raised by that day's topic, which were also covered in additional reading assignments for the day. For example, one week the seminar focused on broad scale patterns of past and contemporary extinctions. Following the seminar, the discussion with the speaker pursued questions of the role of scientists in environmental activism, an issue of interest not only from a career planning perspective, but also to scholars who think about the role that scientists play in shaping social policy. This was a rich and valuable experience for all involved. It is hoped that through this course students will learn some of the hot issues not only in biology, but also in the historical and philosophical study of biological science, and help them prepare for an independent research project in their senior year.

To improve on this last point, Steve Pyne will teach the course this year and introduce more explicitly information about research methods. How does one take a topic or a question and turn it into a package for research in the lab or library, for presentation at a meeting, and for publication? Pyne's own work on the "cycle of fire" history around the world offers a wonderful example. Pyne took fire and divided it up

into many different books, each with its own focus and audience and objectives. The result is powerful, and during this seminar, students will consider why and how to have an impact, each in his or her own way. We also hope that more students will begin taking the course earlier in their careers so that they are best prepared to carry out and write up their own research or thesis projects as products of the independent research required for the major.

In these courses, and in the methods and materials we have adopted, we have made every effort to be explicitly interdisciplinary and keep this purpose foremost in our minds as we proceed, but it is not often easy. Perhaps the biggest challenge for faculty and students has been creating learning experiences that provide the skills necessary to meld creatively alternative approaches to the study of the life sciences. We are pleased with the progress we have made thus far, but continue to reflect on what works and what does not and are anxious to try new pedagogical techniques that show promise.

Other Program Elements

In addition to the major, we offer travel grants for students to attend meetings that bring together issues of biology and society. Each year, we have taken a group to the annual American Association for the Advancement of Science meeting (47 students have attended so far). One year we presented a group paper, which led to an invited editorial in *Science* and a longer article in *Science Communication* (Maienschein, et al. 1999, 1998). These students work as session aides for the AAAS, present posters, and otherwise benefit from this marvelously diverse meeting that is probably the best for larger and interdisciplinary issues of science and society. Several students have become very interested in the area of bioethics. Thirteen students have been funded to attend national undergraduate bioethics conferences, and they have helped design our own undergraduate bioethics retreat. In all cases, students who receive travel grants are expected to write about their experiences in the form of reports, newsletter articles, or occasionally opinion pieces. Travel, and the education and pro-

fessional training that come with travel, has become an important part of our program. Donations support this activity, as does the bulk of our annual operations budget.

The program also sponsors lectures and receptions to bring students and faculty together and to build community. Lectures on bioethics, evolution and creationism, genetics and developmental biology, science policy, the history of gardens, eugenics and sociobiology, philosophy of science, biological warfare, biodiversity: we cover a range of topics. Bringing speakers to campus provides us an opportunity to showcase our program and ask for critiques, and also exposes our students to a wider range of topics and perspectives than is usually seen in a biology seminar series. It has therefore been especially valuable to coordinate the speakers with our research colloquium core course (described above). In this way, curriculum is integrated with extra-curricular activities.

The program is guided by a steering committee, consisting of members from Departments of Biology, Microbiology, Philosophy, and Sociology, with others in Anthropology, Bioengineering, History, and Interdisciplinary Humanities participating actively in various capacities. The director is Professor of Philosophy and Biology.

Assessment

To date, our assessment has taken the form of transcript analysis, student evaluations, assessment of the student research experience, and measures of student success. Transcript analysis reveals that students who have chosen the Biology and Society emphasis are typically above-average students. Most are full-time undergraduates: the average GPA is over 3.40 (4.0 scale), and 40 percent of these students are in the Barrett Honors College. Biology and Society majors often pursue double majors or minors. Thirty percent of our current junior and senior students carry at least one and sometimes two minors, currently in a foreign language, justice studies, philosophy, women's studies, political science and psychology. Double majors currently combine with foreign language, economics, and political science.

Student ratings and comments come most directly in the form of student evaluations of particular courses, and also in response to email invitations for suggestions. The Biology Department as a whole consistently receives feedback that the curriculum and courses are excellent and meet student expectations, but that we need additional advising. This is particularly true of the Biology and Society program since programs are very individual. Our Administrative Assistant, Rita Yordy, will begin training this fall to help advise students on the individualized selection of courses that make up the curriculum. We will also improve our website to include this type of information. Faculty members advise students about the best match for their research projects, and that has been reasonably successful.

The required research experience provides us an opportunity to assess student learning in what amounts to a "capstone" experience. Many Biology and Society students choose to present their research in either an undergraduate thesis defense—10 students have presented public defenses—or papers at scientific conferences—more than 20 students have presented posters at our Annual Undergraduate Research Poster Symposium, the AAAS meeting, or other regional and national disciplinary conferences. These public presentations of research findings undergo peer and faculty review (ASU and external faculty) both prior to and during the event. In all cases, the research has been favorably reviewed. In fact, in two cases the research received awards for best student posters and resulted in student-authored publications. We are currently trying to determine how to translate these successes into learning materials for future students. We are considering developing research project guidelines, more specific grading rubrics, and critical feedback forms based on past projects and reviews.

So far, we have not conducted formal assessment of student success other than keeping track of what awards students receive, whether they publish or present their research results, and such things as where students go after

they graduate. In a university with over 44,000 students, it is notable that our students receive a very high percentage of national scholarships including Rhodes, Marshall, Truman, Udall, Goldwater, Phi Kappa Phi, and such. Since 1997, 15 national scholarships have been awarded to Biology and Society students. Also, several of our students have been successful securing research grants or fellowships, including 15 students who have received Biology Research Experience for Undergraduates fellowships, 6 Scholar-Citizen grants aimed at funding community-based projects, and most recently, a Biology and Society student received one of six Beckman Scholar Development fellowships, which focuses on science communication. The graduates from our still-young program have already gone on to a Rhodes Scholarship in Oxford and London, Teach for America, the Iowa Writers Workshop in Poetry, medical schools, graduate schools, internships in Washington D.C., employment in biotechnology and biomedical areas, science or medical policy jobs, and other diverse activities. While our program alone cannot take credit for these student successes, we are very pleased that this program has supported the academic and professional development of some of the most talented students in the biology department.

We expect students to pursue a diversity of careers and further education. What we have not seen in our first few years of graduates, but what is already beginning to appear in students coming along in the program, is those interested in graduate study in biology. If those students found the program inadequate, we would have to ask why. About half of the current seniors seem to be bound in that direction, however, so we intend to develop an exit survey to assess student satisfaction and perceived quality of the program relative to their interests in a career in biology. We also intend to survey students 1–2 years post-graduation to assess their satisfaction with the program relative to their current educational or professional goals.

Along with the biology department generally, we plan during this upcoming year to articulate more fully what we seek in the way of learning outcomes from our students. We want them to have skills in writing and communicating, critical and analytical reasoning, creative thinking, statistics and mathematics, and to exhibit scientific knowledge and a range of analytical social science and ethics skills as well. The learning outcomes derive from the curriculum requirements, and we will be working on ways to measure student success in achieving them.

The major challenge here is how to assess the "value-added" resulting from the interdisciplinarity of the program. We can find ways to test critical thinking, writing, or statistics skills, for example. But how do we discover whether that can be done across disciplines? How can we evaluate whether a project is truly interdisciplinary, and what does that even mean? We are beginning to look for other models and other guides to help us shape this discussion.

Selling it to the Department: The Program and Supporting Faculty

Our biology department has been very supportive of the creation and support of this program but not without reluctance on the part of some faculty. The reluctance was expressed at two key points in the program's development. First, when we took the proposed curriculum to the faculty for approval, a good deal of discussion followed as to whether or not this course of study was appropriate in a biology department but perhaps more appropriate in a history or philosophy department. Some faculty felt that the core and interface requirements would dilute the rigor of the traditional biology degree under which this option would fall.

We dealt with these concerns in two ways. One was to design the degree so that the scientific rigor of the course of study remained high. As started earlier, Biology and Society students take essentially the same core curriculum of biology, physical sciences, and math courses as our regular majors.

Also we offered the argument that students engaged in such interdisciplinary work needed a solid grounding in science and regular contact with science faculty and students. In essence we asked, what good would a historian of biology be, for example, without a full understanding of biological practices, concepts, and phenomena?

Our department's long history of offering a major in conservation biology helped the faculty see our point. That major had stimulated discussion for years about the optimal level of biology for wildlife managers, and these discussions for some years had consistently produced a consensus that a rich background in biology was of paramount importance in this area. Hence, our arguments fell for the most part on receptive ears and won the day.

With the degree program in place, we then sought the department's support for recruiting faculty with adequate background in the study of biology's place and history in society to support the program. We intended to actively seek historians and philosophers of science to help with our core and interface course offerings. Again, we encountered faculty who were uncertain if individuals with such scholarly interests were appropriate in a biology department.

Our primary tactic here has been to assure the faculty that we would actively recruit individuals with two key characteristics. The first would be that they have a deep understanding and background in biology, as we require of our students. The second was that they were supporters, and not critics, of science. Many of our faculty members were aware of the "science wars" waged between scientists and some strict relativists in the humanities and social sciences, and certainly our faculty did not want to stimulate these wars within the department. Again, we intended to recruit faculty who were not engaged in this debate.

On this count we have been very successful. What has been very impressive is that we have not had trouble finding scholars of exceptional promise who fit this bill. For example, our most recent hire, Manfred Laubichler, has two Ph.D.s, one

in evolutionary ecology and the other in the history of science. He is a superb scholar who is proving very adept helping faculty and students, not just in the program, but throughout the department, see the positive connections that can be made between biology, history, and philosophy.

Conclusions

The program has been of tremendous benefit for students, who were partners in its development. Whereas previously they would have been isolated in their individual pursuit of double majors, minors, and research opportunities, they can now explore issues of biology and society in a community of others of similar interests and backgrounds. The courses and faculty involvement have resulted in a high level of analytical rigor, and in exposure to a diversity of approaches and methods for study. Therefore, asking something like "Should the federal government fund stem cell research?" provokes not just a popular-level response in our students, but also, increasingly, a more sophisticated consideration of what ethical principles, social realities, political constraints, historical contingencies, epistemological convictions, and other forces shape the science and the social response. It is vitally important to the future that we have a cohort of students educated broadly in this way, and also trained deeply in science. These students are likely to be leading researchers as well as social leaders. We need for them to have such a broad, but also rigorous, education. Further, we are seeing this breadth infuse the programs of study of students in other life science degree programs, an unexpected but very satisfying outcome.

In addition, the student interest and the program development have brought the faculty together in valuable ways. Having a label on the program gives it authenticity for many, and it brings support from a wider range of faculty. Recent examples include students who have approached faculty members in political science, philosophy, business, and even law, to serve as members of their research supervisory committees. Whereas in the past, similar students had been told

that they did not have the appropriate or requisite backgrounds since they were not majors in those fields, now these students have been welcomed. The program enjoys the support of our president, provost, dean, and other administrators, which has contributed to the community view that the program is valuable. Other programs are seeking to follow our model, and the program will be highlighted in the undergraduate portion of our university accreditation report currently underway.

After six years of getting the program successfully up and running, a key challenge for us now is to continue improving and developing the program. To this end, we strive to develop effective strategies for assessment that will inform and drive our changes and improvements. As the program grows, we will face new challenges that accompany a larger student body. We must work to put into place the services, new teaching strategies, and new technologies that will allow us to continue the individual attention our current program provides. We also need to inspire stronger, wider, and deeper participation by faculty across the diverse departments that are now part of the program and ensure that the contributions of faculty members are appropriately recognized. This will help deepen the content and offerings of the program and help sustain the program by widening the base of support in the university. We certainly hope that, with these strategies and others outlined elsewhere in this report, in the next six years the program, its students, and its faculty will continue to present the stimulating challenges and opportunities for interdisciplinary studies of biology that have propelled us this far!

References

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