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Non-Science for Majors: Reforming Courses, Programs, and Pedagogy

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Scientific advances fill news headlines and find audiences in popular movies, legislative bodies, and courtrooms, suggesting that society is broadly engaged by scientific issues. Science students typically learn concepts and methods that ignore the social and cultural foreground as well as religious and ethical implications of science practice. These excluded factors often reappear in scientific developments such as genetic engineering of herbicide-resistant plants, environmental effects of chemical and biological waste management strategies, and medical and health implications of sequencing the human genome. Though today's science professors are already burdened by expanded content from introductory to advanced courses, now more than ever we need scientists who are able to articulate non-scientific dimensions of their work and the pedagogical skill help students understand their significance.

To get to that point we will need broad-based changes in science education. This essay suggests transformation at course, program, and university-wide levels. The current focus on covering material, presenting facts, and guiding students through laboratory exercises with known outcomes produces able scientists. Yet this approach leaves students unprepared to reflect on the meaning of science and to understand its broader social and moral context. Changes to science pedagogy encouraged by this essay entail training students to understand scientists as social actors who should reflect on the larger context of their work. With such training, students will more ably communicate the powerful role of science and develop expanded ability to work in interdisciplinary teams. Moreover, exploring the underlying assumptions of scientific inquiry will heighten their respect for the limits—and power—of scientific inquiry. In short, they will be better scientists.

Course level modifications

At the course level, the goal will be to promote broader social, cultural, religious, and ethical awareness among science students. Science educators will benefit from rethinking course objectives in light of science's societal context. Revised objectives might emphasize communication to non-scientists or exploring ethical issues. To accomplish this goal, other course elements (points made in lecture, assignments, exam questions) will need to be deliberately structured to help students see the social connections of science. Ideally, each element will be structured to facilitate assessing progress toward the larger goal. Example assignments include having students write a review of a significant scientific finding for a general audience, teach an experimental technique to non-scientists, or write an essay about their lab work with students from other cultural backgrounds. 'Pre and post' assessment strategies could measure students' increasing awareness of social dimensions of science and their ability to communicate with non-scientists.

Laboratory settings provide another venue for introducing course-level modifications. A significant body of literature suggests that inquiry-based laboratory exercises encourage students to think as scientists do and to discern the non-scientific context of their work. For example, as students learn to formulate research questions, teachers might call attention to questions that cannot be answered scientifically. Such 'mistakes' might well contain assumptions worth exploring. Encouraged to reflect, students will grasp the cultural 'condition of the possibility' of their science work. Other approaches to modifying lab courses require less deviation from established experimental training, but feature creative use of lab exercise 'down time'. While a reaction stirs or an analytical gel runs, students might discuss issues that intersect with the experimental topic. For example, students studying chemical synthesis could discuss progress made in green chemistry and consider environmental and health impacts of chemicals they are studying.

Individual course modifications may be small or large. Recent reports of notable course design projects may serve to stimulate other creative approaches (Strobel & Strobel, 2007; Benore-Parsons, 2006). Using new criteria to evaluate students may yield surprising results. A chemistry student who struggles to write reaction mechanisms may possess excellent understanding of the environmental impact of chemical advances. Such a student might well be directed away from the research lab into a position involving science policy. Expanding the pool of scientists in this way will diversify the scientific community.

Program-level modifications

Program-level modifications have potential to impact a greater number of future scientists. The topic of ethics, a field that intersects frequently with scientific advances, provides an important example. Quite often, science students are not trained to formulate ethical arguments. As a default, they often rely on unarticulated assumptions of their familial or religious upbringing. In all likelihood helping students think ethically about science will require modifying program requirements. Indeed, many institutions are taking steps to integrate ethics into the undergraduate science education (Zaikowski & Garrett, 2004).

An approach that integrates science and non-science learning experiences better will require the support of advisors. Changes might be as simple as helping students choose courses complementary to their interests in science. On a larger scale, departments will need to rethink electives. Inspiring science students to take non-major courses seriously will likely require program modification. Science students ought to be afforded opportunity in their major to integrate learning from across the curriculum; if they are not, the work of intellectual integration will be outsourced to the philosophy and humanities departments. Program enrichment or modification should be guided by a strategic plan and program-level assessment strategy. Good intentions alone are not enough.

University-level modifications

Revising undergraduate science curricula has for some schools become a university-level endeavor. Globalization introduces significant complexity into this undertaking. Because science examines the natural substrate to culture—gravity is the same for the Hindu, Buddhist, and Christian—science training frequently omits exploration of assumptions of science practice, including the role of fundamental beliefs (e.g., that the natural world exists and can be known) and values (e.g., that animals can make only restricted moral claims upon us). Yet globalization raises the likelihood that scientists will interact with people who see essential matters quite differently. Preparing graduates to engage these issues is an immense challenge for the future of science education, one that no department can meet without the university's support.

Encouraging a thoroughgoing multi-disciplinary approach is one possibility. Instead of leaving convergence of disciplines to chance, curricula should be designed to facilitate and require disciplinary crosstalk. Not sequestering students by discipline will allow universities to promote better exchange of ideas. Science students might be encouraged to write articles for the school paper, organize public talks or debates, or tutor in a learning center.

The cost of this approach is significant. Because integrating critical but perhaps unfamiliar topics will be daunting for some faculty, institutions may need to support faculty with released time, teaching assistants, or curriculum development specialists. On a broader scale, institutions may wish to conduct scientific literacy assessments for all students. University-wide curricular projects such as ethics across the curriculum also might be used to further integrate learning experiences.

Costs and benefits

Intentionally planning a modification at any level takes time, not just in course design and lesson planning, but also potentially in working with others and campaigning for changes. Where time is a chief concern, incremental changes can yield cumulative improvement. If one revised one or two items per term, an entire course could be reinvented in a few years. All sorts of transformation are resource intensive. Assessment is important, both as part of pedagogy and as a means of justifying costs. The triad of establishing course goals, managing the classroom and out-of-class learning environment, and performing assessment must be interconnected in order to assess whether a change is effective.

Many of the proposed changes involve asking a teacher to venture into an arena in which she or he is not an expert or that will require new teaching methods (e.g., case studies or classroom discussions about controversial issues). Some faculty resistance is likely. A large-scale strategic plan will need to support mechanisms for dealing with faculty concerns and challenges. Science practice contains a possible solution to resistance. If course redesign, program modification, or university transformation involves experts working toward a common goal, the parallels to scientific research may convince the holdouts**.**

Conclusions

To have a lasting effect, science education initiatives need to be supported at course, program, and university levels. That will require engaging faculty, departmental leadership, and administrators in conversation about curricular matters. As we push for transformations of increasing scale, we should bear in mind that the potential payout is tremendous: meaningfully educated scientists capable of understanding assumptions of their work and thus more able to converse with nonscientists. The next generation of scientists will seek solutions to global warming, environmental sustainability, and the humane use of science and technology. Let us train them well.

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