Frontiers of Science and the Core Curriculum of Columbia College

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The usual approach to undergraduate science education is to segregate "science" from "non-science" students. Actual and potential science majors are pushed into departmental programs to fulfill major requirements; non-science students make do with distribution requirements. Recently, however, science educators have envisaged courses that transcend traditional disciplinary boundaries. For example, the National Research Council's report *Bio2010* (2003) imagines "a truly interdisciplinary course used as an introductory first-year seminar with relatively few details and no prerequisites." This course is designed to "introduce students to many disciplines in their first year, and to hold the interest of first-year students who are taking disciplinary prerequisites." Similarly, the National Research Council's 1999 *Transforming Undergraduate Education in Science, Mathematics, Engineering, and Technology* promotes introductory courses that explore fundamental and unifying concepts and emphasize evolving processes of scientific thought and inquiry.

Most students ("science" and "non-science" alike) enter college having written essays and poems, solved equations, and analyzed historical issues. Very few have actually planned, carried out, and analyzed an actual scientific experiment, in part because what scientists really do is not included in most secondary school curricula. Students view science as a collage of facts to be regurgitated on demand. In reality, however, science is a way of thinking about and making sense of the world. Real science is not what is known but what is to be known. In addition, while the push to interdisciplinary science courses is usually focused on students already within a science trajectory, This perspective is equally important for new students who do not see themselves as connected to science. Frontiers of Science—Columbia's new core curriculum science course—is designed to address both of these issues.

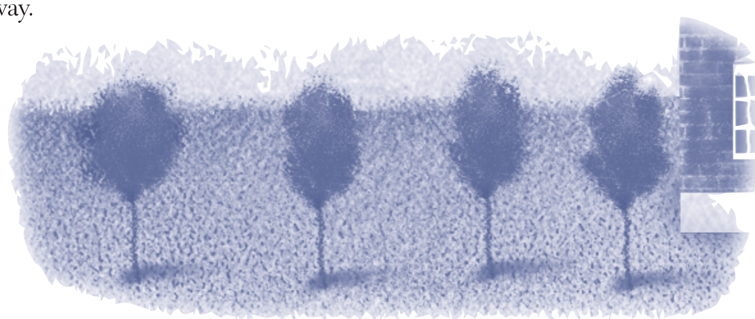
The Challenges of Connecting All Students to Science

Founded in 1754 as King's College, Columbia College is an undergraduate liberal arts college of Columbia University. In 1919, the college began the development of a set of courses that introduces students to essential ideas of music, art, literature, philosophy, and political thought. To foster active intellectual engagement, courses in the core curriculum are taught as small seminars beginning in the first year. As of 2003, the core (specific courses taken by all students) included Contemporary Civilization, Literature Humanities, Art Humanities, Music Humanities, and University Writing. The core curriculum is the hallmark of a Columbia College education.

From the inception of the core, the omission of a science course in the curriculum evoked comment. In 1933, Herbert Hawkes, then dean of the college, stated, "Ever since the course in Contemporary Civilization was offered fourteen years ago, the perennial question of the relation of the sciences to this kind of course has been discussed." It took close to ninety years, however, for those debates to bear fruit. Frontiers of Science entered the core curriculum as a five-year experiment in fall 2004.

Why did it take so long? Dean Hawkes outlined several goals for a core science course in the 1933 annual report: "Meeting the need of all students for a fund of knowledge and a set of intellectual tools that would be applicable in all of their thinking and that would better them as persons" (58). Faculty fights over the new science course erupted right away. Content was a major issue: What constitutes a real core of knowledge in the sciences? Which areas should be included? What about mathematics? Should "science" students be educated together with "non-science" students? Since agreement on content could not be reached, the faculty put together a roster of four courses, half from the physical sciences and half from the life sciences. All were intended for non-science students, none were required, and all courses abruptly ended in 1941 as the war began.

The dormant issue of science in the core arose again after the war ended. From discussions, it became clear to then-College Dean Harry Carman that even though the course would be approved, most of the science faculty strongly opposed it and, since they would be responsible, the original vision could not work. The recommendation reverted to a version—remarkably similar to the 1930s sequence—to be offered at "the earliest opportunity"; that opportunity never arose (127). The science requirement eventually returned to a distributional form: two science courses in one department (for depth) and one in another (for breadth). Since that time, Columbia's small, distinguished science departments have focused on teaching large service courses and smaller courses to their own majors. Many departments did not even attempt to mount a third, stand-alone course that could fulfill the distribution requirement.



Breaking the Science Pyramid

If there is any place where adding science to a general education requirement should be feasible, it is Columbia, home of the much-vaunted core curriculum. Why was science left out? Why was (and is) teaching a broad course in science so hard? One factor was the general consensus among the faculty about what a proper science education should be, a consensus adopted and reinforced by the professional schools, particularly medical schools. This consensus has been most vividly described by Princeton University President Shirley Tilghman's metaphor comparing traditional training in science to a pyramid. In this model, students must complete a foundation of introductory science courses before they can progress to more specialized courses and more engaging scientific questions.

Let's say, for example, that a student is interested in the way the brain handles language. What must she do to take a course on that subject? If she pursues her interest via a biology perspective, she must first take a year of chemistry, then a year of introductory biology, an introductory sequence in neuroscience, and then, finally, she is allowed to enroll in the course that interested her in the first place. However, that first year of chemistry often discourages all but the most determined, which means our hypothetical student might never make it to her original goal.

Suppose that we could break the pyramid. Suppose that it were possible to present the neurobiology of language in a rigorous and insightful way along with other topics at the frontiers of science: global climate change, the origins of the universe, quantum mechanics, molecular motors. This attempt to "break the pyramid" is a defining characteristic of Frontiers of Science. It is at the heart of faculty excitement about the course, but it is also the aspect of the course that arouses the strongest opposition from members of the science faculty.

Steeped in the guild-like tradition of the sequence of courses required to become a physicist or a chemist or a biologist, many science faculty members think that it is impossible to be both interesting and rigorous in presenting difficult subjects to entering students. Further, many view the prospect of teaching outside of their own disciplines (having a biologist teach quantum mechanics or an astronomer teach neuroscience) as either pointless or extraordinarily difficult from the point of view of faculty expertise. As a scientist advances in training, his or her expertise tends to become narrower and narrower. For example, many astronomers, though well versed in mathematics and physics, have not taken a biology course since high school.

What has changed recently is the acceptance of the idea that, to be optimally effective, scientists must acquire cross-disciplinary skills. Nanoscience, the realm of 10^{-9} m (which is on the scale of atomic diameters), is a superb example of a cross-disciplinary forum: at this scale, physics, biology, and chemistry meet and scientific interactions can produce truly novel insights. Most scientists would agree on the importance of educating their replacements; such an education will have to be cross-disciplinary. Students at Columbia can begin to be trained that way through Frontiers of Science. This kind of scientific collaboration, moreover, can be tremendous fun for the faculty, and teaching Frontiers provides a built-in collaborative forum for some of Columbia's best scientists.

A second impetus for the creation of Frontiers was provided by the realization that all students should learn about the analytical tools that scientists use. We all need the ability to critically examine scientific evidence if we are to make wise choices about today's most pressing issues—climate change, stem cells, nuclear technology, transplants—and the problems that we cannot now imagine but that we will have to solve in the future. This set of tools is outlined in Frontiers codirector David Helfand's Web-based text, *Scientific Habits of Mind*. This text provides a unifying theme across the physical sciences and life sciences components of the course. The students meet in seminars to use these analytical skills to tackle scientific problems from the current literature. Their summer reading list before matriculation now includes Bill Bryson's *A Short History of Nearly Everything.*

The high school curriculum typically focuses on the recognized pillars of science: biology, chemistry, physics and mathematics. The college curriculum follows these precepts for science students by requiring courses in each discipline for its majors. Modern science, however, is not limited to these subjects and is now strongly cross-disciplinary. Understanding this synergistic approach is as important for students who pursue majors outside of science as it is for the budding acolytes. By introducing students to different areas of science together with the analytical tools used by all disciplines, Frontiers of Science deals head-on with the real challenges of understanding science today. Students gain an appreciation of areas outside of the traditional curriculum (earth sciences, neuroscience) as well as the way in which knowledge from one desicipline can inspire another.

A running joke in Frontiers is that we must have a *New York Times* spy; it is uncanny how the paper's weekly *Science Times* section tracks Frontiers topics and themes. This coincidence demonstrates that it is possible to enrich faculty members' interdisciplinary knowledge while teaching cutting-edge science to eighteen- and nineteen-year-olds. We acknowledge that the caution of generations of Columbia science faculty was well placed: teaching Frontiers is probably the biggest educational challenge that any faculty member has ever faced. A seminar that includes an Intel science winner and a student who is afraid of math is difficult to get right; it is worth attempting, though, and is tremendous fun. ■

Editor's Note—This article is based on a plenary presentation given at the pre-conference symposium at the 2006 AAC&U annual meeting.

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