Science as a Borderless Discipline

by Diana R. Cundell

Dr. Patricia Chisholm was a new type of university educator in England during the 1970s. She incorporated historical vignettes, folk legends, and social commentary to illustrate her lectures in introductory immunology. All of us, her students, had come from a highly rigid educational system in which science experiments were designed and carried out using the cool, analytical, paced logic of the scientific method and science and non-science subjects were separated by something resembling a restraining order. What a change, then, to enter Dr. Chisholm's world, where scientists had feelings about the experiments they performed and often got things wrong. Even more amazing, we discovered that many successful scientists were eclectic, wild personalities who discovered things through serendipity rather than observation!

Science was now being taught by a pioneering spirit who blazed trails into the unknown and transformed our class into a lively amphitheater in which students and teacher shuttled back and forth from the past to the present and on into the future. Like people who learned the earth was round, our eyes opened and we saw the building of modern concrete science theory on the backbone of what were mostly educated dabblers. Learning became all-consuming as we pored over scholarly tomes to find new evidence supporting the findings of these luminaries and debated their ideas in the classroom. Years before active learning became *en vogue*, we were its embodiment.

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The complex combination of attributes that Patricia Chisholm brought to teaching stuck with me during my medical research years and really emerged when this student herself became a professor. Faced with a sophomore microbiology class full of students close to my own age, I approached the problem of content with one question: "How would Dr. Chisholm do this?" I took the words of Sir Arthur Conan Doyle, himself a scientist, to heart when he said, "Well, I'm a bacteriologist, you know. I live in a nine-hundred-diameter microscope. I can hardly claim to take serious notice of anything that I can see with my naked eye."[1] The first thing was not to limit teaching to the subject itself but also to explore the impact it has on everything else.

The need for a borderless learning experience is apparent for many subjects, but is particularly important for the science major.

Rather than the narrow, microscopic approach common to many microbiology courses, I began instead to incorporate into the course a comprehensive look at the field and its global, historical, and social impacts. Some class sessions showed how folklore and myth translated into reality. Students learned the connection between witchcraft and ergot infection[2] or how the Black Death spread through silk trade routes and that the diagnosis of Hantavirus was helped by accessing Native American legends of the deer mouse.[3] Many were stunned by the social conditions both past and present that prevailed during disease epidemics. One student used an independent study course to read old German manuscripts and assemble an essay on the correlation between ergotism and witchcraft "symptoms."[4] Students wrote deeply personal and moving accounts about how they would have coped with Ebola in Zaire in 1977. They commented on how microbiology was a science without borders and that it related to many things they learned in their humanities and social sciences classes. Like immunology had, years ago, changed my outlook on science, microbiology had for my students risen beyond the microscope to become a real world phenomenon.

The need for a borderless learning experience is apparent for many subjects, but is particularly important for the science major. We are living in an era when a strand of hair or piece of gum can identify a criminal and the blueprint of our genes has been completely mapped out. Continuing to educate students merely in the "how to" of science technique rather than the "what for" or "consequences of" the science is not providing the whole picture. Instead of merely extending the content of each topic, science classes should incorporate any and all information needed to completely understand how each subject works in real-world terms.

Interestingly, this concept has its roots in the transaction philosophy of the great educational reformer John Dewey, who in 1916 noted:

There is a strong temptation to assume that presenting subject matter in its perfected form provides a royal road to learning. ... Pupils begin their study of science with texts in which the subject is organized into topics according to the order of the specialist. Technical concepts, with their definitions… Laws are introduced at a very early stage, with at best a few indications of the way in which they were arrived at. The pupils learn a "science" instead of learning the scientific way of treating the familiar material of ordinary experience.[5]

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Support for the concept of an "integrated science" philosophy may be drawn from four main observations.

First, statistics show that most science graduates come from liberal arts institutions.[6] Between 1986 and 1995, four of the top five most productive scientific institutions were liberal arts colleges.[7] This is in part due to the student/faculty ratio being lower than at comparable research universities, but also because of the diversity of the curriculum.[8] At a 2003 symposium, Dr. Michael Doyle, professor of chemistry at Trinity University, suggested that one reason for the success of the liberal arts institutions is that "boundaries dividing departments and disciplines are, or need to be, fading in order to accommodate a new set of burgeoning, complex academic areas."[9]

Doyle suggests that we need to aim for a "science across the curriculum" to produce graduates who are truly science literate.[10] This is a feeling shared by Muriel Lederman, associate professor of molecular and cellular biology at Virginia Tech, who wrote in a recent *Chronicle of Higher Education* article, "Incorporating discussions of the social dimensions of science into science courses broadens students' understanding of current theory, tools, analytical techniques, and how different disciplines investigate and interpret the natural world".[11]

Second, much of the subject matter of science is poorly understood without recourse to a discussion of social policy, economics, and cultural disparities.

Third, the loss of many otherwise capable science majors may be linked to an inability to connect with the rigid practice of science.[12] This is especially true for female and minority students who are unable to identify with the strict and often uninvolved classical science curriculum and may explain why fewer women than men choose to pursue postgraduate degrees in the sciences higher than master's level.[13] More women than men are now enrolling as science majors at undergraduate institutions.[14] Furthermore, this gender disparity in college enrollment is projected to increase, with more women earning bachelor and master's degrees, but with doctorate students still predominantly male.[15]

It follows that the more integrated the curriculum is, the more likely students—especially women and minorities—will identify with it and become absorbed by it. Several experts suggest that incorporating social studies and real world issues into the science curriculum is an excellent way to achieve this goal.[16]

Fourth, continuing to divide the curriculum sharply between science and non-science issues may help make those we teach less civically minded in the long term. One of the mission directives from a recent summit on developing citizenship in young people was "creating a civic identity that includes commitment to a larger sense of social purpose and a positive sense of affiliation with the society."[17] Again, making clear social or economic consequences for scientific actions or concepts is clearly important in developing engagement in our graduate science majors who will later make the science policies of our society.

Once we accept that science needs to have no borders, the next question is how to achieve this, given the finite amount of time to be spent on each class. High school science educators raised this question in a 2000 Internet discussion forum called Diversity and Discover. Participants repeatedly cited two problems: (1) a polarization between science and non-science subjects and (2) trying to balance each in terms of classroom time. In addition, many of the instructors continued to be strong adherents of the classical science teaching methods, with in-depth knowledge of scientific areas being precedent. Indeed, the philosophy of science is still etched on many an instructor's mind as being "a system of acquiring knowledge—based on empiricism, experimentation, and methodological naturalism—aimed at finding out the truth."[18]

In tackling this problem of content versus scope in my own upper-level science courses in microbiology, immunology, and histology, I have used a variety of strategies to make the courses borderless, most of which involve considerable extracurricular research by the students. First, I accelerate traditional note taking during lectures by providing the students with dedicated note packets for each course. I prepare and update each subject on a biannual basis, using both Internet and textbook material, and add appendices for important information annually. Second, in laboratory classes, I include basic technologies appropriate to the science class, in addition to instructor-generated mini-case histories (microbiology) or oral, professionally oriented, case history presentations (histology). I first introduced mini-case histories to my microbiology class in 1997 as a new problem-based learning exercise to provide a fresh and real-life approach to science.[19]

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I presented scientific findings either associated with a patient being admitted to hospital or as an environmental issue. Students had to evaluate the evidence and explain how they came to their conclusion or, if they couldn't come to a conclusion, state what information was missing. Initially, students worked in groups of three or four for 10 to 15 minutes to discuss the case histories and work through them. Next, students made a list of all possible diagnoses suggested by this information and worked cooperatively to determine the suspected pathogen.

Since then, I've used mini-case histories to cover immunology and histology. In addition, for junior-level histology students, the course has encouraged development of professional and empathic skills using oral case history presentations. Students in pairs are provided with an embryological or pathological human condition, which they are required to research in depth and then present to their peers in two ways. First, the pair of students takes the roles of health practitioner and patient portraying the interaction as realistically as possible. Then, one of the students explains to the class the histology behind the condition as well as treatment and outcome prognoses. At a later date, this pair of students will again portray a selected pathology with the second student explaining the etiology of the condition. Feedback from several of these students, now medical school graduates, indicates this assignment was a great preparation for grand rounds, as well as improving oral presentation skills.

Third, I use various writing assignments that allow students to explore a variety of witing and documentation styles, including preparing a newspaper article, personal journal, and formal research presentation. Fortunately, our university has an active writing across the curriculum program, and my colleagues there helped me set guidelines and format source material for these assignments, most of which span several disciplines. Using these guidelines, students are able to see science as a creative discipline where facts can be laid out in a variety of ways to accomodate-different target audiences. Many students balk at these assignments in the beginning but eventually find the personalities and cultures behind scientific events and discoveries fascinating, as I did nearly 30 years ago.

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Finally, I use a culminating class debate at the end of the semester to complete the integration of the disciplines being covered. For the microbiology students, the premise is that a global catastrophe has necessitated the construction of a new "Noah's Ark" with room for only one living microbial kingdom.[20] For immunology, the premise is that only one component of the immune response can be retained, with the two others eliminated. Students working in teams research and then orally present the merits and pitfalls of each living kingdom or arm of the immune response. As sources, they use Web-based information, books, journal articles, and media information.

Each student presents for five to eight minutes on his or her topic and, once all arguments have been presented, the groups respond to the criticisms raised. At the end of the period, students vote for the group whose speakers have provided the most persuasive argument, although this is not a component of their grades. Debates have proven to be lively events that involve posters, PowerPoint presentations, and, on average, three to four hours of research per student prior to the event.

Research has shown these methods to be effective and to have helped students approach assignments more creatively. Interestingly, when a subset of my students were polled in an anonymous questionnaire, 76 percent said that just the study guide alone allowed them to be more adventurous in exploring the areas that they found most engaging during class. In the words of one student, "I didn't have to wade through the textbook trying to find all the information, so now I had a chance to read things that I found stimulating."[21]

Teaching science as an integrated subject in this way is not easy. For a single instructor-driven course, it requires a broad range of subject knowledge and interests. The preparation time required for managing the courses and grading assignments is daunting. Some institutions have solved the issue of subject knowledge by pairing science and non-science faculty or offering courses that lend themselves well to an integrated approach, such as medical anthropology.[22]

In the words of the Binghamton University staff who teach a co-curricular integration of science and social/historical concept classes, "We want students to discover for themselves how much of the humanities and social sciences depend on advances in science and technology, and how developments in society can encourage, or hold back, scientific and technological progress."[23]

What has seemed to produce the best effect is to use a variety of approaches in both engaging and keeping the interest of the students.

The feedback from students at Philadelphia University has been overwhelmingly positive. Students have commented that inclusion of different approaches to writing science (e.g., newspaper reporting or historical diary compilation) has broadened their horizons. For some, *The Coming Plague* videos[24] were the first time they realized how culturally and economically different the United States is from African and Asian nations; they were astonished at the disparity. Mostly, as in the Binghamton University model, what has seemed to produce the best effect is to use a variety of approaches in both engaging and keeping the interest of the students. In the words of one environmental and conservation biology student, "The integration of technology and other resources offers more educational opportunities for the students, who in return will receive a better education. It is always a good thing when a professor uses the available tools and alternative methods to the lecture models when teaching students. While some aspects may not work, use of these tools usually only has a positive effect on the class and the students."[25]

In the words of the Irish essayist and journalist Robert Lynd, "There are two sorts of curiosity—the momentary and the permanent. The momentary is concerned with the odd appearance on the surface of things. The permanent is attracted by the amazing and consecutive life that flows on beneath the surface of things."[26] Stimulating this permanent curiosity will ensure that the scientists who graduate from our institutions will possess a broad and deep understanding of their fields, allowing them to flourish in the multi-disciplinary world without borders that is theirs to inherit. A borderless world also allows me to honor my mentor Dr. Chisholm, who taught me to be permanently scientifically curious without defining limits for that curiosity.

ENDNOTES

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