



## Science Education in Different Cultures: Unity and Diversity

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IT IS A LITTLE DIFFICULT to know just what introductory speakers at these gatherings are meant to do. Such a speaker has a resemblance to a body at an Irish wake; it is necessary to have one, but nobody expects it to say very much. I am also a little intimidated by the title I was given for this talk: "Science Education in Different Cultures: Unity and Diversity." A friend of mine, a developmental economist, was asked recently to give a lecture on "Poverty, Hunger, Justice and Conflict in Relation to Industrialization in the Northern and Southern Hemispheres." He wrote back and said that though he was touched by the invitation, he did not want to be restricted by such a narrow title. "I would be happy to accept," he replied, "if you would add in . . . 'and the Sun, the Moon, and the Stars'."

I feel much the same way about the topic today. So, I wish, if I may, instead of talking about science education in different cultures, to talk more generally about science, and include within that science education. I should also say that I am clearly not an expert at this. An expert is somebody who arrives by jet from at least five hundred miles away, carrying slides and a briefcase. I have arrived with no slides-only with a manila folder and an umbrella-and I have walked about five blocks from the other side of the campus. But I believe the topic is not only of interest to those of us in academic science but also of vital concern to all nations. The purpose of our gathering, as I understand it, is to encourage and facilitate overseas study by students, by faculty members, and by other practicing scientists. In the interest of full disclosure, I should note that I am a product of overseas study; years ago I came as a Fulbright Fellow from Britain to the United States. And, therefore, I am both a product and an advocate of that particular kind of study.

Let me first ask a simple question: "Why bother to go abroad? There is so much here, so why bother to go abroad?" That may seem a fairly obvious question. But I can't help recall trying to emphasize the value of study abroad at Cornell some years ago. Some of the most resistant individuals were faculty members in the language and literature departments, who argued that all the instruction needed was available right here on campus. Why go abroad when there is such a wealth of talent and riches within our community on our own campus? I think there are probably two major immediate reasons that people go abroad, as well as two or three lesser reasons, ones that I would call strategic reasons.

The first major reason is access to people. I went abroad to study with somebody-Harold Scott of the University of Illinois-who happened to be an expert in the field in which I was interested, and I was not disappointed. That was a wonderful experience, and for a year I had the opportunity to work in a different university setting, in a different context, and in a different culture. But gaining access to people is wider than access to a single mentor; it may mean gaining access to several people, or gaining access to a research team, or gaining access to a new kind of

intellectual community. These are opportunities for which it is necessary to go abroad.

There is a second major reason to go abroad, and that is access to facilities, equipment, collections, archives, libraries, and even phenomena. If you are interested in the taxonomy of cycads, you need to go abroad to study them. If you are interested in the physiology of the emperor penguin, you need to go to Antarctica to study them. If you are interested in vulcanism and island arcs, you leave the continent and go to the oceans around the continental margin to study them. Clearly there are linguistic, economic, social, anthropological studies, as well as archives and collections, that require the same access. Access to people and access to facilities, phenomena, and collections are the two immediate reasons that most people go abroad.

But I suggest there are also more strategic reasons for encouraging international study within the sciences. The first is this: the development of science, perhaps more than the development of any other product of human culture, is international. No one society, no one nation or continent, can claim credit for the development of science; it is the product of a glorious interwoven fabric of different civilizations, each of which has contributed something to its development. It goes back to Egypt, with the development of astronomy and mathematics and the practical outcomes they produced, ranging from such things as the calendar, for example, to architecture and art. One thinks of Babylon in developing cuneiform writing, the development of records so vital to science, the three-hundred-and-sixty-degree circle, and the sixty-minute hour. One thinks of the Greeks with their marvelous contributions in zoology, botany, medicine, physics, and geometry, and the many practical applications of these and other discoveries-how they measured the diameter of the earth and developed the concept of specific gravity. One thinks of China with its remarkable contributions to our understanding of magnetism and seismology; of the Arab world, with its studies of mathematics; and of a handful of other civilizations. All these made essential contributions to the development of science. Science is an international creation, a global undertaking, and its roots go back to ancient civilizations.

But it is a striking fact that modern science is not the direct descendant of Greek science. It arose only by the conscious rejection of much of the Greek world view. Aristotle, for example, explained gravitational attraction as the result of the pleasure involved when bodies move toward one another. It was only by the rejection of the notion that inanimate objects could exhibit human qualities that modern science developed in the sixteenth and seventeenth centuries in Western Europe. Modern science came into existence, not as the direct descendant of Greek science, but rather in defiance of ancient fashion and wisdom.

Let me quote two different authors to illustrate this point. One is a historian, Herbert Butterfield of Cambridge; the other, a philosopher, mathematician, and educator, Alfred North Whitehead. In describing the cultural web in which modern science developed, Butterfield writes as follows: "There does not seem to be any sign that the ancient world, before its heritage had been dispersed, was moving towards anything like the scientific revolution." Out of the score of ancient civilizations, not one produced modern science. That is not to say, of course, that none could have done so, but the fact is that none did. Alfred North Whitehead, pondering the same question of the origin of modern science, writes, "When we compare this train of thought in Europe with the attitude of other civilizations when left to themselves, there seems but one source for its origin. It must come from the Medieval insistence, of the rationality of God, conceived as with the personal energy of Jehovah and the rationality of a Greek philosopher."

The use of modern science was thus not a linear development, not a kind of intellectual orthogenesis. It was, rather, by challenging some of the prevailing everyday assumptions, implicit beliefs, and prevailing views that the progress of science was shaped; it is this cultural web, the set of questioned and unquestioned intellectual assumptions, in which discoveries take

place. In the case of the rise of science, these included the belief in a regular, intelligible universe, the belief in the principle of rationality, and the belief that human intelligence is capable of grasping the workings of that rational, dependable universe. These were the foundations for the rise of modern science. These beliefs depended on both the acceptance and rejection of various earlier culture influences.

That process is not limited to the sixteenth and seventeenth centuries in Europe; it is something that still operates today. The best science is likely to flourish within a healthy variety of different cultural assumptions and competing viewpoints. The future of science is likely to benefit from the diversity of people and debate, just as science has done historically. Copernicus, Galileo, Kepler, Newton, Harvey, the Curies, Darwin, Mendel, Einstein-these people had very different backgrounds and very different views of the natural world, but each contributed in major ways to the progress of science.

Let me suggest a second strategic reason for going abroad; the intellectual context and social context of science have profound influence, not just on its development but also on its application. History suggests that the greatest benefits of science emerge within a rather distinctive cultural context. If one looks at Western Europe in the nineteenth and early twentieth centuries, for example, one sees a dazzling range of practical inventions, from vaccination to the use of radioactivity, the steam engine, the locomotive, the gasoline engine, the automobile, wireless telegraphy and, by the mid-twentieth century, such things as television, radar, jet propulsion, and antibiotics. A comparable list could be produced for the United States.

The pursuit of science and its optimum application seem to flourish particularly in societies with three characteristics: The first is personal freedom, without which science cannot exist. Science advances by posing impertinent questions-not just impertinent in terms of the reigning universe, but in terms of reigning paradigms. Science grows, in part, by questioning prevailing explanations and conventional answers. That will not easily happen where personal freedom is lacking. Second, the pursuit of science and its effective application involve open communication. At the height of the Napoleonic wars, in the midst of the bitter conflict between Britain and France, the British Admiralty shared its newly developed navigational tables with the French Navy, believing that the benefits to international navigation were even more important than the particular needs of the war. Science is now international in scope, and its human benefit is also international, but it can take place only in an atmosphere of freedom and open communication.

A third requirement seems essential: there has to be a fiscal, industrial, and economic context in which scientific invention and its application are encouraged, although there are those who would question whether we have yet achieved such optimal conditions in any part of the world.

Open criticism, open communication, the encouragement to nurture ideas to practical ends: these are the conditions that encourage the pursuit and the application of science. And if you want to see the difference between two cultures, consider, if you will, the difference between Lysenkoism and cold fusion. Lysenkoism developed in what was then the Soviet Union in the 1930s and persisted for almost thirty years. T. D. Lysenko was a Russian agricultural geneticist who argued for the inheritance of characteristics acquired through environmental influence. For thirty years in the former Soviet Union that was the reigning theory in agricultural genetics. Although it was ultimately overthrown by the sheer weight of evidence against it, it took thirty years under an authoritarian system for a faulty theory, backed by the government, to be lifted and for alternative theories to be considered. Compare that, if you will, with cold fusion. It took a month or two in total for cold fusion to be rejected, and the difference between these two cases is the difference between an authoritarian society, on the one hand, with closed communication and an 'official' view, and an open society with open communication. All societies, of course, are

now becoming more open, and fax machines, e-mail, the telephone, and CNN have reduced the possibility of a repetition of Lysenkolsm. 50 open communication, open criticism, personal freedom, and an economic and social system that supports discovery and provides the tools for its development are the requirements of a healthy scientific enterprise.

Let me give a third, strategic reason for international study of science: the practice of science itself is increasingly international. For example, Cornell has a cooperative agreement with Nanjing University in China that goes back almost seventy years. As a result of that agreement there has been an agricultural revolution in modern China, the seeds for which were planted in that early cooperation.

If one looks at the discovery of the structure of DNA by Watson and Crick, an international team, and the development of biotechnology that has followed it, with all its multitude of applications, one sees again the importance in the practice of science of international cooperation. Jim Watson happened to go to Cambridge, where there happened to be someone with whom he wanted to work. Would this landmark discovery have been made, had it not been for the international journey that Watson made? I am sure that it would, at some stage, but clearly this particular discovery was a direct result of one graduate student happening to go abroad.

From international cooperation in things like earthquake prediction, to the cooperation in the Antarctic, where forty-two different nations occupying forty bases work together as though national boundaries did not exist, we see the benefits of international partnerships. The practice of science often requires international cooperation, just as the benefits of science are international. From conservation to health, to nutrition, to economic growth, to new materials, to new sources of energy, to population policy—the benefits of partnership flow both ways, and that is the way it should be.

One of the most striking examples of double directional benefit is a program called Cornell-Oxford-China Study in Nutrition. For fifteen years, Cornell's Dr. Colin Campbell has worked with colleagues from Oxford and the People's Republic of China in a study of the nutritional habits and backgrounds of a large population in the southern part of China. The conclusions drawn from that study are now being applied to the ultimate benefit of people in other countries, both developed and developing.

It is also true that your students and our students are increasingly international students. Sixty-one percent of the doctoral degrees in engineering awarded in this country go to students from other nations, as do 41 percent of those in the natural sciences, and 28 percent of those in the social sciences. One of the encouraging things about this international movement of students at the Ph.D. level is that it has now become a twoway process. What was a brain drain in earlier decades has now been reversed in some cases; six thousand Ph.D. scientists, mathematicians, and engineers are now returning every year to Taiwan from other parts of the world, for example.

But the real question is not just whether international science is a desirable undertaking, but whether science itself is prospering internationally. We just had Reunion Weekend on the Cornell campus, with five thousand alumni from all over the world streaming back to the campus. This is always an exciting time, as we talk about individual careers and international developments. One alumnus with whom I had a long talk is a brilliant young biochemist, a Ph.D. from our medical school. He completed his Ph.D. with great distinction, published five papers, and has had four years as a postdoctoral fellow at NIH. He has produced a dozen significant papers. I asked him what he was planning to do next year, and he said—to my amazement—"I am

going to law school." I said, "You cannot be serious," for this is one of the most able young men you can imagine. But he insisted he was serious and that he was going to work full-time in the patent office and go to night school for a law degree, because he is convinced that there is no future for him in science. Now I believe you can replicate that story in other situations and probably in other countries.

The challenge, it seems to me, is not to develop some cozy intellectual agreement that international study is a desirable thing to undertake, but to ask the question, "Will there be opportunities available to today's young scientists to work in international cooperation in the years ahead? Will the opportunities we had as younger people still be available to them? Are we supporting science at a responsible level?"

Let me give three examples of the threat to the health of science in different countries. In the United Kingdom the total federal capital budget for basic science is £1.3 billion and that budget is now controlled not by the Ministry of Science or the Department of Scientific and Industrial Research, as it once was, but by the Department of Trade and Industry. What will the motive for fundamental science be in the years ahead as the budget is constrained and as the priorities for national economic development continue? What will the motive be? What will the criteria be for fundamental research?

A second example: the Ukraine of the former Soviet Union has about ninety thousand scientists, engineers, and professional technicians, among whom they are now conducting a major peer review. That review is being conducted because there is virtually no money even to heat the buildings in which these people work. The review will decide which of the different pursuits it will be possible to sustain and which ones must be discarded.

Or look at the United States: most recent budget forecasts predict that real dollar support of science by the turn of the century will be reduced by somewhere between 12 and 22 percent, even though the need for federal support of science, engineering, and mathematics has never been greater. Support for science depends on presidential and congressional budgetary decisions, and those depend, in turn, upon public understanding of the role of science. So we face unusual problems in this country in the years ahead as we wrestle with the support of science. I ask very simply, then, if the dream we have of international study and cooperation for scientists with adequate facilities and equipment for research is to continue, what should we do as scientist-citizens? If war is too important to be left to the generals, then I believe science is far too important to be left to the politicians. Scientists must become scientist-citizens and advocates for a balance and adequate level of support for science. What, then, should we do?

I want to suggest five things, most of which we can do for ourselves most of which do not require funds, but all of which involve additional personal effort. First, I believe we must take seriously our responsibility to nourish and develop youthful talent in science and mathematics. We are losing young people in science and mathematics before they reach the doors of the university, and that is especially true in the United States. In elementary schools, U.S. students compare favorably with students in other parts of the world on scientific and mathematical tests. But by the time they get to middle school, U.S. students have the lowest mathematics scores of any group in the world. And female students are forty-five points lower on math SAT scores than male. This is a challenge that must be confronted. It is no good complaining that teacher unions get in the way of real learning. It is no good complaining that there aren't enough qualified physics teachers or mathematics teachers in the schools. We, the practicing scientific community, have to become engaged. There is no other solution. If not we, then who will be responsible? This engagement will take time. It will take effort. It will not necessarily take more resources. Seventy-five percent of local budgets in this country already go into the schools,

leaving only 25 percent for everything else, so it is unlikely that we can put more money into schools. We can, however, improve the schools. We need scientists who are willing to become leaders in local school boards, PTAs and their equivalent in other counties, and volunteers within those schools. We must nourish young talent. If we don't, we shall have no students.

We must also develop new ways to cultivate and nourish young talent. How do we do it? There is no silver bullet, but clearly small things help. Local newspapers have athletes of the week. In the future might we not have a science student of the week? Local competition in athletics is everywhere; why not in science? Why not science fair-type competition? Much more generally, why aren't articles in the media supporting the need for this? Can we not contribute op-ed and other similar pieces? We must become partners with the schools in coming to grips with what is clearly a serious deficiency at both the pre-high school and the high school stages.

Second, not only must we develop and nourish youthful talent; we must also improve science teaching at our universities. We have an undistinguished record as teachers of science, especially in the introductory courses in many of our large universities. Nationwide, we lose in the first year of college and university 35 percent of those who enter as students registered in science, mathematics, and engineering. These able young people, capable of achieving degrees, often turn away because of the inadequacy and dullness of our presentation. We need to capture the enthusiasm as well as train the intelligence of our first-year students. If we do not take seriously first-year teaching in the colleges, then science cannot have a viable future. This a task not for the least able or most junior faculty but for the best people, the best scientists, and the most thoughtful researchers in every department of every college. We have work to do in our own backyard, especially with the quality of teaching for first-year college students.

Nor can we limit our concern to science majors. We must also reach out to the students who are interested in other areas of the curriculum. We need to make sure that our departments and disciplines are open, friendly, and welcoming to all students. That is not an invitation to softness or to dilution of disciplines, but a call to present them as challenging, significant, inviting, and exciting - words that do not readily come to mind in the curriculum of many science departments, with notable and wonderful exceptions.

Third, we must raise the scientific literacy level of the citizenry at large. We shall not succeed in that, I think, by using an army of experts in Washington or depending on our professional trade associations. The problems that confront modern society are increasingly technological and scientific; they range from population, to environmental quality, to conservation, to materials, to health, to defense. All require the contribution of scientific knowledge. In response to that need, we must take seriously courses in the university for nonscientists. We have to rethink, recapture, and redesign the curriculum across campus, recognizing that science must have and must contribute to a cultural base. We live in a scientific world highly dependent on modern technology. Science is an essential part of the culture of the twenty-first century. We as faculty have lost the curriculum. We have allowed it to be shaped course by course, individual by individual. It is time to revisit this topic and recapture the curriculum, establishing a central base of science as a means of cultural understanding. That is not to diminish the role of comparative literature or the humanities or the social sciences or the fine arts, but it is to assert that within that matrix of knowledge, science must play a role. So, we must educate scientist-citizens.

Fourth, we must become public advocates for investment in science-in Washington, in state capitals, and in the capitals of other nations. We must become tireless advocates for more national and international investment of science for, unless we do, we cannot hope for success. I refer not just to success in science, but to the larger success and well-being of the nations we represent. Increasingly, we are dependent upon the infrastructure of science and the wise

application of technology that in many countries now faces the threat of erosion. We must develop a more stable pattern of public investment in science, not to the exclusion of other needs and areas but as an important contribution to those needs and areas. We shall never solve the infrastructure problem or the housing problem without serious study of new materials and new technologies, for example. No company is going to undertake that kind of long-term applied research, but it is an essential contribution to the infrastructure of this and every other country.

And I believe we must become advocates for the international study of science. The future of science can be guaranteed only if it is enriched and cross-pollinated with viewpoints other than our own, if it is fertilized by questioning existing norms and challenging prevailing assumptions. That has always been the pattern in which science has developed. Although today it is tempting to look at science as a completed edifice, in which all the pieces are in place, science is, in fact, a continuing creation, with a continuing need to challenge existing assumptions. Remember the bumper sticker from the sixties: "Question Authority"? I think we need to "Question Assumptions" constantly, for only in that way will science grow. And it will grow best if we have the benefit of different cultures and different international viewpoints in challenging the conventional assumptions.

So here are the challenges before us: We must develop and nourish youthful talent. We must take seriously the challenge to improve teaching in our own colleges and universities. We must devote ourselves to the education of citizen-scientists. We must become advocates for investment in science. We must become practitioners and enablers of international study. If we do that, not only will science, and science education prosper, but we shall in our own time make added contributions to the prevention of disease, to improving food supplies, to conserving resources and to the larger well-being of humankind. But it cannot happen in national isolation. We need to remove the barriers to international interchange and make sure that science funding is maintained at a realistic level. If science teaches us one thing it is this: individuals can change the world.

But, you say, these new responsibilities-praiseworthy though they may be-will simply take too much time, more time than you have to give. My answer is that if there is to be a scientific infrastructure in which you pursue your work, these responsibilities are the price of preserving it. Individuals can change the world. Copernicus changed the world. Darwin changed the world. Einstein changed the world. They changed the world by changing the cultural matrix of the generation in which they lived. And you can change the world; this group here today can change the world.

There is a story I like, which was once told by President Kennedy. It concerns Marshal Lyautey, the great marshal of France, who in his retirement years became a devoted gardener. Lyautey said to his assistant gardener, "I want you to plant that tree, without fail, today." And the gardener replied, "What is the hurry, Marshal? That tree is one of the most slow-growing that I know; it will take a hundred years for it to reach its full maturity." To which the marshal answered, "Then in that case there is not a moment to lose. Plant it at once." That is the urgency of the challenge that faces us today in international science. We must plant these five seeds of action at once.

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