Guest Comment: Making physical science courses valuable to nonscientists

In an editorial nearly a decade ago, John Rigden[1] described an important problem which plagues most introductory college physics courses. These courses present physics to students as a systematic and detailed string of *answers* without giving them a chance to gain a good understanding of the *questions* which might motivate a real interest in knowing the answers. This motivation is essential. We can't expect students to struggle through the difficult and often tedious process necessary to understand the answers presented in physics, if they have no basis for connecting them to questions that are of significant interest and concern in their own lives. In order to get the most out of the material presented to them, students must *want* the information, and this will only happen if they appreciate and value the questions answered by that information. Otherwise, as Rigden described it,

> ''...first we sedate our students with exhaustively detailed answers to a plethora of unmotivated 'Hows?' When we finally get to the questions of intrinsic interest, the 'Whys?,' many of our students could(n't) care less.''

Rigden's criticism of introductory physics certainly remains relevant today, and is even more applicable to physical science courses for students not majoring in science. In the case of the introductory physics course for physics and engineering students, we at least have the advantage of students with prior interest and experience in the subject. They might be able to supply the ''motivation,'' left out of the course itself, from their own background knowledge. In the case of nonscience students, such an expectation is entirely unreasonable. We are more likely in this case to encounter students whose backgrounds have already convinced them that physics is entirely *irrelevant* to any questions that matter to them. Nevertheless, most physical science courses for nonscientists suffer from the same shortcomings described by Rigden for introductory physics. The course is treated as a list of topics to get through. The great triumphs and progress of physics are illustrated by showing the major *solutions* that have been obtained to questions whose importance is taken for granted by practicing physicists, but whose relevance and importance is far from obvious to the typical liberal arts student in the audience. Most physicists may be willing to accept any solution explaining some previously unknown part of nature as a valuable accomplishment. Most students in a course for nonscientists will *not* accept this assumption, and will continue to treat what they are being told in lecture as irrelevant to them unless they are rather persuasively shown otherwise.

While the impact of technology is the most commonly used argument for the value of science, there is an often-ignored angle which I suggest provides an ideal framework for a physical science course which is relevant to a class of nonscientists. This angle is the impact our knowledge of ''how the world works'' has on our everyday attitudes, which underlie most of what we do in our lives. For example, the goals and actions of a society which believes the universe is a relatively small ''stage'' on which human actions are carried out and judged might be quite different from those of a society which sees the earth as a physically tiny part of a much vaster universe. Often the desire by scientists to avoid any contact with questions of meaning or purpose[2] keeps them from using this theme to motivate interest in science. But, while the separation of science and values in scientific research may improve our chances of getting the results ''right,'' it is only *important* that we succeed in getting the physics right if in the end we do feed the information back into answering the ''why'' questions most people really care about.

I think the lack of emphasis on this last step in the process of science is largely responsible for the widespread feeling that basic science is impractical and irrelevant to most people's daily lives. This sentiment is an indication that most people are missing out on the most important benefit of science, because they do not see the direct connection between the world described by science and the ''personal'' world they experience every conscious moment. I suggest that the role of a physical science course for nonscientists is to establish this connection, and thus enable the full benefit to society of scientific research to be realized.

To ensure that a course fills this role, we need to begin by making students consciously aware that most of their lives consist of choices that are primarily controlled by a set of beliefs they have about how the world basically works. This set of beliefs, which I refer to as an individual's ''personal cosmology,'' determines most of what we consider practical and relevant. Though we're often not even aware that we hold these beliefs or where they come from, they influence such varied things as the religion we follow, the kinds of products we buy, the clothes we wear, the types of careers that are most ''practical'' for financial survival, whether or not we recycle, the kinds of entertainment we enjoy, where we live, what political candidates we support, and so on.

This discussion of personal cosmologies at the beginning of a course grounds the class in issues that are unquestionably of relevance to all students. Once the students have been guided into recognizing that they have personal cosmologies, the discussion can turn to how these have developed in the past, and what kinds of information would cause the students to modify them. At this point, the students are ready to make the connection to science. We can lead the students to generate *questions* out of this common background, and structure the rest of the course around the pursuit of answers to some of these questions.

In the case of an introductory astronomy course I taught, I made the following suggestion to the students: Just as their family and cultural background influence their personal cosmologies, how they think the rest of the universe around us is arranged, how it operates, and what its history is can have a profound impact on the personal cosmologies they hold. I explained that the course would be about exploring the answers to particular questions about how the universe is arranged, how it operates, and the processes that have occurred that have made it possible for us to be here.

With this introduction, I had shown the students directly that the story of the universe we would be discussing in class was the foundation for their individual stories, so that studying physical science might be of some interest and relevance to them. It might even be one of the most relevant subjects they had ever studied! With this kind of background, there is real hope of getting students to struggle through the difficulties to find some answers, because they really care about the questions being asked. They'll also be more willing to put up with the sometimes unfamiliar skepticism characteristic of science, because they have a vested interest in getting things *right*.

The details of what questions are attacked in the course, and how they are linked to the background discussion, will, of course, depend on the particular type of physical science course and the expertise of the instructor. In the case of my astronomy course, the central question was to determine the scale and arrangement of the stars we see in the night sky. This was easily motivated in the context of our background discussion by pointing out that the design of a stage certainly affects the kind of play which can be performed, and that the structure of things around us forms the stage in which our lives are carried out.

Whatever the questions chosen, the rest of the course should be a *self-contained* process of understanding and carrying out methods of answering these questions. By self-contained I mean that we should carefully avoid making anything done in the course look arbitrary. Any mathematical or measurement tool is introduced in order to answer some question. Nothing should be presented merely as an exercise to be learned for no obvious reason. In fact, the more difficult and involved a particular technique becomes, the more important it is to continually remind the students of the question we are trying to answer using this technique, and to invite them to propose easier solutions. Then if they start getting frustrated they at least remember there is a good reason for doing it.

To summarize, I suggest that in our teaching we should make a more deliberate effort to maintain the links between *questions* of real interest, generated from the students' world of experience, and the science we present to them. If we can maintain these links, not only will we be much more effective in teaching our subject to nonscientists and in gaining the support of the public who fund our research, but the understanding we gain in the process will put us in a better position to best direct our own work toward one of the most important values of science: a better understanding not just of ''the universe,'' but of *our place* in the universe in which we find ourselves.

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[1] John Rigden, ''Editorial (11): The principles of physics are grand…let's use them,'' Am. J. Phys. **54** (11), 971 (1986).

[2] Freeman Dyson, ''Time without end: Physics and biology in an open universe,'' Rev. Modern Phys. **51** (3), 447–460 (1979).

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NATURAL SELECTION IN PHYSICS

The process by which theories are selected according to their agreement with observation (as well as their coherence and generality) is not so different from biological evolution, where genetic patterns are selected according to whether they tend to lead to organisms that have progeny. But I was not to appreciate fully the parallel between the two processes until many years later, when I had learned more about simplicity and complexity and about complex adaptive systems.

Murray Gell-Mann, *The Quark and the Jaguar: Adventures in the Simple and the Complex* (W. H. Freeman and Company, New York, 1994), p. 76.

PROPRIETARY DATA

The issue of proprietary data is the source of much difficulty within the conduct of modern science. Some would say that, aside from the plethora of engineering faults plaguing *Hubble*, such data rights are the single most corruptive influence on the Space Telescope mission. Proprietary concerns, protected targets, ''legal ownership'' of this or that star or galaxy are symptomatic of professional paranoia, and derive from an innate distrust among scientists—a fear that one scientist will steal another's data; all the while few scientists realize that the data are not theirs to own. *Hubble's* science data are the property of the citizens of the United States and Europe, or should be.

Eric J. Chaisson, *The Hubble Wars* (HarperCollins, New York, 1994), p. 349.