Portland State University
PDXScholar

Physics Faculty Publications and Presentations Physics

1999

Approaching Critical Thinking Through Science

Linda A. George
Portland State University

Jack C. Straton
Portland State University, straton@pdx.edu

Follow this and additional works at: https://pdxscholar.library.pdx.edu/phy_fac

Part of the Physics Commons
Let us know how access to this document benefits you.

Citation Details
George, L. A., & Straton, J. C. (1999). Approaching critical thinking through science. The Journal of General Education, 48(2), 111-117.

This Article is brought to you for free and open access. It has been accepted for inclusion in Physics Faculty Publications and Presentations by an authorized administrator of PDXScholar. Please contact us if we can make this document more accessible: pdxscholar@pdx.edu.

One unanticipated development of University Studies is the degree to which it rapidly became seen not just as general education, but as the replacement for all generally required courses. Because the natural sciences had comprised one of the distribution areas of the old program, expectations that the new program would teach science quickly flowered, although exactly what faculty mean by that term has yet to be established. In fact, discussions of what we intend by science education have brought increased attention to these expectations as we continually revisit the goals of University Studies. The matter is far from resolved, however, as natural scientists themselves continue to grapple with what constitutes, if not the essential definition of scientific understanding, then at least one that is meaningful and instructive. Meanwhile, University Studies faculty have introduced a wide range of scientific practice—both natural and social—into their courses as important forms of critical thinking.

APPROACHING CRITICAL THINKING THROUGH SCIENCE

Linda A. George
Jack C. Straton

Introduction

While Freshman Inquiry courses focus significantly on skill building, they are also expected to provide coverage of multidisciplinary content. Meeting these somewhat competing goals places a severe limitation on the amount of subject matter that can be presented from any one discipline. While this limitation is always somewhat frustrating, it is particularly challenging to the many science fac-

JGE: THE JOURNAL OF GENERAL EDUCATION, Vol. 48, No. 2, 1999.
Copyright © 1999 The Pennsylvania State University, University Park, PA.

ulty who, like ourselves, perceive the delivery of content to be our primary educational goal. Successful participation in Freshman Inquiry required us to reevaluate this perception, to take a hard look at what it is about science that we expect *every* student to understand and then how to present that content in ways that would enhance the goals of University Studies, especially critical thinking. Our approach was to prune, rather than simply dilute, our disciplines to make this fit. While it may or may not be a radical solution, it was certainly a difficult one.

There are 3 major ideas about science that we address during our year-long course called Values in Conflict: how scientists make truth claims, knowledge and uncertainty, and science and social responsibility. It would have been easier if we had started with this conceptual framework and built our assignments around it, but it turned out that we recognized this structure only in retrospect, by analyzing the ideological goals of the assignments we developed over the 1st year. The process of thinning and pruning our disciplines (Di Stephano, 1996) while developing components of the course led us to formulate our assignments around these three concerns. Using them as our anchors, we will discuss the assignments we developed using components from our disciplines that illustrate the larger themes we have identified.

How Do Scientists Make Truth Claims?

Before beginning to work with issues in science, we find it useful to discuss what science is and is not. As a starting point, Steven Lower's computer-aided activity "Science, Non-science and Pseudoscience" (1998) provides some good working definitions of the terms *hypothesis, theory*, and *scientific fact*. In addition, the interactive program guides students through issues that attempt to frame the domain of science: what kinds of questions science can and cannot address, what kinds of practices distinguish science from other types of knowledge, and so on.

The most fundamental means by which most natural scientists make and support claims is experimentation. For example, to incorporate this aspect of the scientific enterprise into the course, we ask the students to make some simple measurements with magnets, analyze the magnitude and effects of magnetic fields, and then describe their kinesthetic experience of a very similar gravitational field. Due to the limitations of working in a nonlaboratory setting, devising relevant experiments is challenging and actually conducting them produces a sense of incongruity in the midst of a class that normally centers on reading, writing, and discussion.

We introduce discovery-oriented activities, where students develop and test a hypothesis to explain an imploding pop can, or engage in an experiment that requires choosing items from a grab-bag of common household items to use as "tools" to estimate the volume of air one breathes in a day. These experiments are used to engage students in a combination of problem solving and scientific thinking.

As part of this segment of the course, students are asked to evaluate the assertion that Creationism is a science. We are careful not to ask students to determine the validity of Creationism; rather, based on their understanding of what constitutes science, we ask whether or not Creationism is, as its proponents argue, scientific. In this project, students are challenged to evaluate the claims and arguments presented on the World Wide Web by the various groups and individuals who are involved in this debate. Thus, students are exposed to the idea that the definition of science itself is contestable and has implications for scientific research, education, and public policy. All these activities serve multiple goals: to educate our students about scientific definitions and processes as well as to examine the way they understand and construct their own and others' arguments.

Knowledge and Uncertainty

Students tend to have polar views on the nature of scientific knowledge. On the one hand, there is a sense that knowledge that has been derived scientifically is "factual" and is closer to "Truth" than other ways of knowing; on the other hand, once students have been exposed to the notion that knowledge is mediated by one's perspective (Tompkins, 1986), this is often misunderstood to mean that there is no "real" knowledge since "everything is biased."

These epistemological issues are ones that scientists tend to ignore, but we bring them into the course because they connect directly to issues of diversity and multiculturalism. For example, students read essays about scientists who are not white or male and discover that, throughout the history of science, the fact that science is done by human beings who have socially constructed "perspectives" has a significant influence on what kinds of science get done and what kinds of conclusions are arrived at.

We unpack the subject of "knowability" by exploring wave-particle duality in the quantum world. We first demonstrate "conclusively" that light is made of waves and then provide "proof-positive" that light is made of particles. We next show photographic evidence that matter, too, has both particle- and wave-like properties, so that *wavicle* might be a better descriptor. Next, we discuss the social controversy over welfare and take students through a parallel series of steps that reveal a paradox like the wavicle: the rich are often in favor of cutting welfare, but if welfare is cut, starving people will turn to crime or revolution, neither of which is in the interests of the rich. The ultimate lesson is that if we get stuck on any particular perspective in science or society, we are likely to be missing much of what we *can* know.

Science in Society

One unfortunate development in our educational system is that science usually is thought of and taught as a discipline different from every other. The result is that science does not usually appear in "nonscience" courses. This is in stark contrast to the way we actually live; in modern American society, questions involving science and technology are among our chief concerns. Consequently, we examine the role of science in societal issues in many contexts, using historical documents, fictional accounts, and contemporary issues in modern society.

We begin our examination of science and society by studying some historical clashes between scientific knowledge and other ways of knowing. The first incident is introduced via "Galileo Galilei," Bertolt Brecht's dramatization of the sixteenth-century scientist's conflict with the Church of Rome, in which Galileo insists, based on his astronomical observations, which were contrary to the religious beliefs of the time, that the planets revolve around the Sun. In our examination of this issue, students work through an interactive set of digital movies, stills, and text that allows them to understand the scientific issues at stake in this controversy. A second clash is dramatized in the movie "Inherit the Wind," based on the 1925 Scopes trial (the so-called "Monkey Trial") in which a Tennessee law prohibiting the teaching of evolution was challenged. In both cases, social authority and scientific knowledge conflicted and resulted in social banishment of the offending scientist. From the perspective of many students in modern America, these scientists are the heroes, the victims of ignorant communities. To balance the debate, students read Mary Shelley's *Frankenstein*, in which the dangers of scientific knowledge are dramatically depicted; the students explore the need for the consideration of societal norms in the pursuit of scientific knowledge.

By the end of the year, the students have examined the role of science and society in history and have gained skills in group process, research and analysis, and Internet use. As a finale to the year, we developed an extensive role-playing exercise to give them the opportunity to apply these skills to an actual issue. In the Portland Air Quality Project, students engage in a process that decision makers must go through in order to determine and implement public policy. By focusing on an environmental issue, we are able to study the interactions between science and society in the development of such policy.

We start the project with an analysis that defines air pollution in the Portland area as a problem that can only be improved with the reduction of emissions of some classes of pollutants. In order to address this, students must acquire some basic concepts in polluted air chemistry, which they obtain from class lectures and their own research. Students are then divided into various stakeholder groups (e.g., Auto Manufacturers, the Petroleum Industry, Citizen Groups, Government Regulators, Industrial Representatives, and Environmental Activists) that are concerned about the way the emission reduction will be implemented. Each group is required to develop a detailed stakeholder position statement, which they generate in consultation with the actual community stakeholders they represent. Ultimately, decision-making groups are formed by incorporating members of each stakeholder group; the decision-making groups must then agree on an implementation plan for reducing air pollution in Portland. This exercise provides students with insight into the complicated ways societies make decisions in which scientific knowledge is only one part.

Summary

Incorporating science into a multidisciplinary course for freshmen has been a challenge. But the reward has been a sense of success in incorporating nontraditional subjects and techniques as a means to get scientific concepts across to those who may have an aversion to science. In fact, we have found ourselves using the techniques we developed for this course in our conventional science courses. Of particular importance are discovery-oriented activities, such as developing and testing hypotheses, which engage students in problem solving and thinking scientifically, and the use of computer graphics whenever visualization accurately portrays the underlying mathematics. By the end of the year, the students have gained skills in scientific investigation and analysis and have examined the role of science in society and the influence of societal values on scientific practice.

In furthering the goals of Freshman Inquiry, we have found that the thoughtful, in-depth integration of fewer topics and processes from our specific scientific disciplines has been much more effective, although more challenging, than presenting a diluted, broad-spectrum science curriculum.

The reluctance of some science faculty to participate in multidisciplinary courses may be due, in part, to a fear of "dumbing down" the content. In contrast, our experience has been that the integration of science into the multidisciplinary context of Freshman Inquiry meaningfully expands the breadth and depth of discourse. Omission of science from this type of course would deprive students of an opportunity to examine "scientific ways of knowing" alongside other ways of knowing, thus preventing a truly holistic investigation of the human desire "to know."

References

Di Stefano, R. (1996). Preliminary IUPP results: Student reactions to in-class demonstrations and to the presentation of coherent themes. *American Journal of Physics, 64* (1), 58.

Lower, S. (1998, April 27). Science, non-science and pseudoscience. <http://www.sfu.ca/chemed/Science.html>

Tompkins, J. (1986, Autumn). 'Indians': Textualism, morality, and the problem of history. *Critical Inquiry, 13* (1). Rpt. in H. L. Gates (Ed.). (1986). *Race, writing, and difference* (pp. 101–19). Chicago: The University of Chicago Press.

1. A sense of the challenge can be gained by seeing our working description of the course (the complete title of which is Values in Conflict: Knowledge, Power, and Politics): "The over-arching goal of the Values in Conflict course is to help students become conscious participants in their own value systems and to help them examine the conflicts that occur in society when perspectives collide and individual rights conflict with social and community responsibility. The multifaceted roles of science, technology, ethics, and social distinctions are central to the discussions, including examinations of racism; global and regional environmental conflicts; the impact of culture, gender, and politics on scientific discovery; the role of ethics in the practice and development of technology; and the role of art in politics and activism. Students have the opportunity to write and act in dramatic productions; to read plays, poetry, essays, and novels; to take part in group environmental projects; to create political art; to write about and discuss issues of culture and diversity; and to explore the scientific method through formulating hypotheses and carrying out experiments."