Teaching Science in Cultural Context with an Optional Travel-abroad Component

Vladimir N. Garkov

Mary Baldwin College, Staunton, VA 24401, vgarkov@mbc.edu

Abstract

The recently developed course called Science in Cultural Context introduces students to the spirit of science (and chemistry in particular) as a process as opposed to a specific body of knowledge by employing the multidisciplinary tools of philosophy, history, and geography of science. The first unit covers the birth of modern science in Europe from a historical perspective. The second unit teaches students the main ideas and accomplishments of chemistry from Lavoisier to Schrödinger and Watson and Crick. The philosophical aspects of science are considered in the third unit which looks at science's uncertainty, recentness, completeness, objectivity, and unity. Special attention is devoted to the unnatural character of the scientific way of thinking. Unit four tries to answer Yali's question about the reasons for Europe's scientific and technological superiority by exploring the physical geography of science. The fifth unit of the course compares ancient cultures and discusses the cultural geography of science including the religious, economic, political, and other human factors that gave birth to the scientific way of thinking in only one place – the agora of ancient Greece. The last unit of the course is an optional trip to Europe, to places like Italy, Russia, southeastern Europe (Bulgaria, Greece, and Turkey), or central Europe (Austria, Germany, the Czech Republic, and Paris). The course may also be conducted entirely on the campus of the American University in Bulgaria. The travel component allows students to (i) study the cultural and geographic aspects of science by visiting museums, laboratories, schools, hospitals, and sights of historic and artistic significance; and (ii) explore the European culture, study the communication patterns, and look for the elements of the scientific discourse by conversing with the locals (including local university students) and by observing how people relate to each other. The travel-abroad component presents our students with the opportunity to understand the role of science in the society from a cross-cultural perspective while helping them to appreciate and evaluate their own US culture more critically. The course uses the following texts: *The Ascent of Science* by Brian L. Silver, *Uncommon Sense: The Heretical Nature of Science* by Alan Cromer, *Guns, Germs and Steel* by Jared Diamond, and *Germany - Unraveling an Enigma* by Greg Nees or *Exploring the Greek Mosaic* by Benjamin Broome.

Introduction

Most students perceive chemistry as a difficultsubject. I see three main reasons for its difficulty: (i) the abstract nature of the material, which is not readily applied to real-life situations; (ii) the need to learn a whole new vocabulary of terms and symbols that are almost never used in everyday life; and, (iii) the heretical character of scientific reasoning which doesn't come naturally to humans (Cromer, 1995).

The challenges of teaching non-science majors are somewhat different from the challenges of teaching science majors. Many educators including a former president of the National Science Teachers Association have indicated that all efforts to instill rational thought into non-science students have been largely fruitless (Shamos, 1995). This is attributed to the fact that "so much of modern science defies common sense". Therefore, the goal of a general education course in the sciences should be perhaps not so much the attainment of a certain level of scientific knowledge and terminology as the effort to impart to our students the spirit of the scientific enterprise which will help them appreciate science. In a similar manner, we teach art appreciation without expecting our students to necessarily create art. In other words, we could try to teach not chemistry per se as a practice but rather to teach *about* chemistry as a science. Unlike the pieces of art, though, whose beauty is not a matter of experimental evidence, the appreciation of the products of science like pharmaceutical drugs or nuclear power requires a specific level of comprehension of the laws that govern the behavior of matter in this universe.

There are many pedagogical approaches, which have been developed to help general education students appreciate science as a way of knowing. In our department we teach physical science using the integrated approach of *The Sciences* (Trefil and Hazen, 2006) in a studio course where lab and lecture are taught simultaneously. In addition, I have been using *Chemistry in Context* (American Chemical Society, 2003) in a two-semester sequence of two courses. (The second semester of this sequence is called Chemistry and Society and is open also to science majors who have completed a semester of general chemistry.) I find this book superb in terms of its innovative ways of teaching chemistry in an *environmental* context. Therefore, I thought that a new course that teaches science in *cultural* context will complement the environmental approach adopted by the ACS.

Teaching chemistry and general science through the multidisciplinary prism of philosophy, history, and geography of science is only one of many ways we all try to reach our general education students. This course is different from other general education offerings in three of its aspects: First, the emphasis is on areas of study that are usually associated with the humanities. Second, the level of chemistry knowledge and quantitative reasoning is at its bare minimum. Third, instead of a laboratory experience, the course contains an optional travel-abroad component.

Course outline

1. Historical aspects of modern science and its origins in Europe

2. The ascent of chemistry

3. Philosophical aspects of science

4. Physical geography of science

5. Cultural geography of science and its origins in ancient Greece

6. Central Europe as a case study of science culture (optional travel-abroad component)

Course description

During the first class meeting students take a long survey which explores their philosophical worldview of science in general and that of chemistry as the science of matter. Several years ago, a sociologist colleague of mine and I developed this survey, whose idea is to study the effect of student's cultural, national, and educational background on his or her worldview. Survey questions try to determine students' familiarity with, for example, the scientific way of investigation, the experimental method, the organization of knowledge, the difference between social and natural sciences, the historical development of science, the roles of gender and ethnicity, etc. In addition, students answer Likert-scale questions about their views concerning the impact of chemistry on society. Students have often indicated that the process of taking the survey itself is an important learning and thought-provoking exercise. The survey in its entirety is attached to this paper as a separate document.

The first book that students read for this class is *The Ascent of Science* by Brian L. Silver, a physical chemist (Silver, 2000). This text starts with the concept of motion, energy, and the molecular nature of this world. The presentation is linked to a quick historical tour at the dawn of modern science from Newton to Descartes to Bacon emphasizing the ways in which people's thinking developed on the cusp of reason, empiricism, and religious beliefs. The main philosophical ideas in science are further explored with the study of deductive and inductive reasoning, as well as Popper's falsification criterion vs. Kuhn's paradigm shifts (chapters 1 and 2).

Next we continue our studies using Silver's text with the study of Newton's laws of motion and how he was the unintended catalyst through which the

French *philosophes* promoted the triumph of reason, the diminution of God, the development of deism, and the ascent of science in Europe (chapters 3 – 7). This is followed by a discussion of a backlash, the *Sturm und Drang* movement and Rousseau's romanticism. Then we continue with the second industrial revolution (of the 1880s) which was based heavily on the study of electromagnetism, and Volta's and Faraday's experiments and which gave birth to the professional scientist and the beginning of the fusion between science and technology (chapters 8 – 11).

The second unit, called the ascent of chemistry, is dedicated entirely to chemistry and biochemistry. Students study from a historical perspective "the material trinity" of the atom, isotopes, nuclear reactions, the periodic table, bonding between atoms to form molecules, the types of solids, ceramics, polymers, and liquid crystals, the nature of light and waves, chemical and physical changes, heat and motion, and the laws of thermodynamics (chapters 12 – 18). This is followed by the study of elements of the quantum theory, the photoelectric effect, the concept of quantization, the ideas of Schrödinger, de Broglie and Heisenberg, quarks and leptons, and relativity (chapters 28 – 31). We continue with the birth of genetics as a science including evolutionary theory, the structure of DNA, cells, and the origin of life (chapters 20 – 27). The coverage of the material is purely conceptual and there are very few quantitative examples.

The third unit builds upon students' general knowledge of science's advancement and explores some general aspects of modern science: its predictive power, the uncertainty of measurement, the impossibility of completely specifying the initial state of a system (position of a molecule), the ecological "chaos" (chapter 19), the philosophical aspects of science, its social impact and relationship to other ways of knowing (chapters 36 and 37). The course then moves on to a second text, *Uncommon Sense: The Heretical Nature of Science* by Alan Cromer, a theoretical nuclear physicist (Cromer, 1995). Chapters 1, 2 and 8 of that book look at some important aspects of science – its recentness, completeness, objectivity, and unity including the central argument of the book – the unnatural character of the scientific way of thinking. Cromer's thesis is that the formal, logical thinking needed for math and science represents an abnormal mode of thinking, which may not be beneficial to an individual from a historical and evolutionary perspective. The use of intuition appears to be a faster and more natural way of solving everyday problems.

The most important goal of the third unit is to introduce the idea that science is not a body of knowledge but a *process*, a way of thinking, the "search for a consensus of rational opinion among all competent researchers" which contains three essential elements:

- recognition that an *external reality* exists out there independently of our minds and independently of any supernatural force;
- interest in trying to figure things out driven by sheer *intellectual curiosity*, not necessarily by a desire to create something useful; and
- *general skepticism* including readiness to discard one's scientific views or even one's cultural/religious beliefs when they contradict new experimental data.

Unit four of this class uses Jared Diamond's best-seller *Guns, Germs and Steel* (Diamond, 1999). The author is an evolutionary biologist and biogeographer whose writings combine anthropology, biology, ecology, linguistics, genetics, and history. First, students are asked to try to answer (in writing) Yali's question: Why did the Europeans have so much "cargo" and the native peoples of the other continents didn't? After discussing all proposals, we try to focus on the development of science as a way of thinking which may be the ultimate reason for the world's scientific, technological, and material inequalities. We explore the crucial role of physical geography for the development of science. The different positions of the continents along Earth's axis lead to different abundances of species available for domestication and different levels of closeness to the animals, different levels of food production (surpluses) and different population levels, different levels of urbanization and social stratification, different levels of literacy, different social organization (including the irrigation hypothesis), and finally different levels of material production in Europe and southwest Asia as opposed to the rest of the world over a period of 10,000 years.

In unit five, we continue exploring the answers to Yali's question by returning to Alan Cromer's text and by studying the cultural geography of science. If the physical conditions shape the cultural landscape, what made the culture of ancient Greece so unique that it developed formal logic and objective thinking? We follow Cromer's tour of intellectual human history from apes to modern times (chapters 3 – 7). We study the way of thinking in ancient Israel, the Arab science, the Chinese technological innovations, and the Hindu mode of thought in a comparative manner. The emphasis is on the role of religion and the different levels of separation of internal thoughts from objective reality across different cultures. Students follow the author's argument that the discovery of deductive reasoning and the scientific way of thinking could have occurred in only one place on this planet – on the agora (the marketplace) of the city-states of ancient Greece some 2500 years ago. The ancient Greeks gathered and argued different issues in an atmosphere of freedom of expression and philosophical curiosity about the world around them. Over the centuries, this independent way of viewing and thinking about the world was carried on by the Romans and later by the Byzantines after western Europe fell into the dark Middle Ages. With the gradual destruction of the Byzantine Empire in the hands of the Ottoman Turks in the 1400s, many Byzantine scholars fled to Italy. Those scholars carried with them the torch of the humanistic way of thinking that was characteristic of ancient Greece and eastern Christianity. This torch together with crucial influences of Islamic translations of ancient Greek works that came to Europe through Spain ignited the Italian Renaissance, which eventually spread the spirit of science to all of Europe – from Lavoisier's Paris to Mendeleev's St. Petersburg.

Travel-abroad component

The last unit of this course is an optional travel-abroad component. I have taught this course four times over a period of 7 years, and I am offering it again in May 2008 during our upcoming May term. May term is an intensive 3-week part of our academic calendar when students take only one class. Students taking this class receive two weeks of on-campus instruction which is followed by a trip to Europe. Another format for the same course is to offer it spring semester and use spring break for travel or to teach it entirely on the campus of the American University in Bulgaria or a similar overseas institution. Because of the extra cost involved and because of the size of our student body (750 residential students), the number of students enrolled in the class has been small – between 3 and 6 people. Together with colleagues from other schools who taught other courses, we have traveled to different destinations: Italy, Russia, southeastern Europe (Bulgaria, Greece, and Turkey), and central Europe (Austria, Germany, the Czech Republic, and Paris).

The travel component has two main goals. First, it allows students to study the cultural and geographic aspects of science by visiting museums, laboratories, educational institutions, hospitals, and sights of historic and artistic significance. For example, outside the city of Veliko Turnovo, the medieval capital of Bulgaria, there is a small village called Arbanassi, which has preserved its houses and churches from the Renaissance period. The Church of the Nativity of Christ (15th – 17th century) in Arbanassi contains frescoes which are not found anywhere in the West.

As shown to the left, instead of the twelve apostles, Jesus' family tree is surrounded by ancient Greek philosophers and thinkers like Plato, Aristotle, Solon, Plutarch, Pythagoras, Homer, Galen, the oracle Sybille, and Socrates. Most interestingly, all these non-Christians are depicted with halos.

The so called "wheel of life" in the same church contains elements of the early scientific way of thinking in Renaissance Europe, showing the astronomers who observe the sky and predict future events in a Copernican heliocentric world. In contrast to western religious traditions, the image of the Christian God appears above the wheel looking like Zeus (note the picture to the right):

The frescoes in this church bring our students to a discussion of the meaning of God in human cultures, the close link between the jovial ancient pagan gods and the Greek Orthodox worldview, the differences between Orthodox Christianity and Catholicism, the connection between religion and the natural world and daily life, and the role of the church in preserving ancient Greek culture and philosophy during the 500-year long period of Ottoman Turkish rule. The role of religion as a catalyst/inhibitor of science and as a different way of "knowing" about the world is an essential element of this course.

The second goal of the travel experience is to present students with the opportunity to explore the European culture, to study the communication patterns and to look for the elements of the scientific discourse by conversing with the locals (including local university students) and by observing how people relate to each other. Students read and we all discuss at least one scholarly text on intercultural communication. I have used two books from Intercultural Press. The first one is *Germany - Unraveling an Enigma* (Nees, 2000). The author describes the communication patterns that are found in Germany, which are typical for much of central Europe: criticism and negativity as a social ritual; directness and Klarheit (clarity); application of critical intelligence to public issues; Diskussion; thoroughness and strong appreciation of the past; Unterhaltung (meaning *both* conversation and entertainment), vertiefen (going into detail); willingness to express and argue your point of view; exactness and Verbindlichkeit (obligatory bindingness); and Sachlichkeit (objectivity, lack of offense, impersonalness).

The above-listed characteristics of the German language and the communication patterns in Germany (and central Europe) appear to be essential for the development of the scientific way of viewing and thinking about the world. Communicating with local students and people on the streets, and learning about the ways of another culture inevitably leads our students to comparative discussions about the American culture and helps them acquire a fresh perspective on their own way of life. For example, issues like global warming, the use of nuclear power, public transportation, recycling and environmental protection are discussed from a perspective of citizens of poor countries like Bulgaria. Furthermore, students learn about the different approaches to education and health care as well as to ethnic and gender issues found in different nations. Both education and medicine loom large in the social context of science. Reflecting back on their own US culture is an important learning experience for our students.

The second intercultural communication book is *Exploring the Greek Mosaic* (Broome, 1996). This text discusses the communication patterns in Greece many of which are commonly seen throughout the Mediterranean region from Spain to Italy to Turkey. Students observe the lifestyle of the peoples living in this part of the world, which is centered on intensive human-to-human interaction and deep relationships. Like Unterhaltung and Diskussion in Germany, “kouvenda” (conversation and entertainment) and argumentative battles are dominant in Greece. The sense of conflict and the notion that the unexamined utterance is not worth hearing form the core of Greek life. The pedestrian streets and squares with their numerous cafes have replaced the ancient agora (birthplace of the scientific process) as the focal point where people gather to idly wonder about the world and argue for hours their points in heated debates around cups of coffee and cigarette smoke. This common European phenomenon is a showcase of some of the essential elements of the scientific way of thinking – debate, logical argumentation, and criticism – thus emphasizing the central goal of the course: to help students understand the spirit of science and its ways of looking at the world. The travel-abroad component presents our students with the opportunity to understand the impact of science on the society from a cross-cultural perspective while helping them to appreciate and evaluate their own US culture more critically.

Course evaluation and conclusion

Given the non-standard format of this course, it has been offered only on a pass/no-credit basis. Students who are not pressured by GPA considerations seem to be more relaxed and free to explore and discuss beyond the boundaries of the material. Even though this course is perhaps the most humanities-friendly offering for non-science majors it is also quite appropriate for science majors because our curriculum rarely allows any time for exploration of the geo-historical and philosophical aspects of science. In fact, chemistry majors who took the course wrote in their evaluations that they found it fascinating, enriching, and much needed for science majors. Students earn 3 credit hours by taking it. Participation in the travel component may bring an additional 1 credit hour if this is the way the course is organized, which has been the case for other courses using a similar format. In my experience with Science in Cultural Context, all students took part in the travel portion and received only 3 credit hours.

This course is an effort to synthesize culture and science, to unite cultural and scientific literacy. In my view, cultural literacy may be defined as knowledge of the development of the world through time and space (i.e. history and geography) including appreciation of the arts and literature (Garkov, 2000). Cultural knowledge appears to be the primary civilizing force that binds people together socially by providing them with a meaningful perception of their own individual lives as small but integral parts of the larger story of humankind. The study of the humanities and the arts has a humanizing effect by uplifting the young soul above the material world into the world of ideas. In contrast, the study of the physical and life sciences may have an opposing, "dehumanizing" effect by rationalizing our lives and emphasizing reality. In other words, the natural sciences provide the basic, material *means* for our existence, while the humanities show the humanistic, non-material *meaning* for one's presence on earth. Therefore, the integrated approach to teaching chemistry in combination with history, geography and philosophy of science may help students appreciate and understand the nature of the scientific process in a holistic manner.

Literature cited

American Chemical Society (2003) *Chemistry in Context: Applying Chemistry to Society*. McGraw-Hill

Broome, B.J (2006) *Exploring the Greek Mosaic: A Guide to Intercultural Communication in Greece*. Intercultural Press, Yarmouth, Maine

Cromer, A. (1995). *Uncommon Sense: The Heretical Nature of Science*. Oxford University Press, USA

Diamond, J.M. (1999) *Guns, Germs, and Steel*. W.W. Norton & Co.

Garkov, V.N. (2000) Scientific or cultural literacy? A transatlantic perspective. *Academic Questions* 13, No. 3, 56-70

Nees, G. (2000) *Germany - Unraveling an Enigma*. Intercultural Press, Yarmouth, Maine

Shamos, M.H. (1995). *The Myth of Scientific Literacy*. Rutgers University Press.

Silver, B. L. (2000) *Ascent of Science*. Oxford University Press, USA

Trefil, J and Hazen, R.M. (2006) *The Sciences: An Integrated Approach*. Wiley.
