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The Other Culture: Science and Mathematics Education in Honors

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The Other Culture: Science and Mathematics Education in Honors

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national collegiate honors council

THE OTHER CULTURE: SCIENCE AND MATHEMATICS EDUCATION IN HONORS

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PREFACE

The National Collegiate Honors Council (NCHC) has established over the years twenty-two standing committees, only one of which deals explicitly with curricular disciplines: the Science and Mathematics Committee. It is a widespread and relatively accurate perception among NCHC members that the academic strengths of most honors programs are focused primarily in the humanities, with also a sizeable fraction in the social and behavioral sciences. In a survey conducted several years ago for the NCHC[1] for example, only fifteen percent of honors administrators reported having an academic background in the natural sciences, and three percent in mathematics. Forty-nine percent listed an academic affiliation in the humanities, and twenty-four percent in the social and behavioral sciences.

Several reasons are likely for the apparent modest involvement of faculty from the natural sciences and mathematics in honors programs, chief among these being the fact that these disciplines may be perceived—if erroneously—by their practitioners to be less conducive to the small group discussion format favored in honors environments generally. Perhaps a more difficult problem to resolve is the fact that tenure-track faculty in the natural sciences may be subject to rigid time constraints vis-a-vis laboratory or field research that, together with the complementary duties of administering often sizeable research grants, can detract from the availability of such faculty for the kind of intense and time-consuming involvement with undergraduate students that is characteristic of honors coursework. Finally, it should be said that—with some exceptions, obviously—departments of natural science and their faculty often do not put as high a premium on excellence or innovation in teaching, perhaps in part because they place a greater emphasis on research activities, given the appreciable sources of external funding available in these disciplines, relative to the humanities and even the social sciences.

One adverse consequence of this situation, of course, is that honors programs often have difficulty arranging for honors sections of coursework in mathematics and the natural sciences, and especially in arranging for the participation of faculty from these disciplines in team-taught, interdisciplinary offerings. The implementation of this latter pedagogical tool—which is becoming increasingly popular with some honors programs—may also encounter problems if participating faculty from the natural sciences insist upon incorporating laboratory or field work into the curriculum, since such facilities may not be readily available to humanities-based programs.

While national data on the declared majors of honors students are apparently not available, U. S. Department of Education statistics on bachelor's degrees awarded by field for all students indicate that the percentage choosing to major in the natural sciences and mathematics averaged 10.4 between 1995 and 2000, while the corresponding value for humanities majors was 6.1 percent.[2] While it cannot be known if students majoring in the natural sciences and mathematics are less inclined to participate in honors programs that have a strong humanities-based focus, there is no reason to suspect that their numbers are lower in honors programs generally. It is a matter of interest then to all honors administrators and faculty to understand how programs that have been successful in incorporating the natural sciences and mathematics into their curricula have accomplished this, and what ideas and options might be available to those still seeking to achieve such a disciplinary integration.

It is axiomatic in honors education that no two honors programs in the country are identical. Whether literally true or not, this diversity of form and function in honors education is at once both a great source of inspiration and ideas for these many programs—especially those in the formative stages—as well as a quite tangible barrier to the writers of monographs such as this. These authors strive to make some sense of this potpourri of organizational and pedagogic matters and to provide useful generic guidelines and practical help to the administrators and faculty of these many program types. I think you will find that the editors and authors of the present monograph have succeeded admirably in this task.

—Dail W. Mullins, Jr.

Notes

[1]Survey by Ada Long in 1995.

[2]*Chronicle of Higher Education Annual Almanac*, 1999–2000; 2000–2001; 2001–2002; 2002–2003.

INTRODUCTION

The Other Culture: Science and Mathematics Education in Honors

> "I now believe that if I had asked an even simpler question—such as, What do you mean by mass, or acceleration, which is the scientific equivalent of saying, *Can you read?*—not more than one in ten of the highly educated would have felt that I was speaking the same language. So the great edifice of modern physics goes up, and the majority of the cleverest people in the western world have about as much insight into it as their neolithic ancestors would have had."
>
> —C. P. Snow, *The Two Cultures*[1]

In the now-famous lecture given by C.P. Snow in May 1959, he raised the issue of scientific illiteracy in the halls of academia and called for practitioners of science, the humanities, and social sciences to build bridges to increase human understanding of our world.[2] Thinking that this issue was resolved in the last half century would be nice, but it may have actually become worse.[3] As Dr. Dail W. Mullins, Jr., points out in the Preface, two cultures are alive and well in the world of honors education. Scientists and mathematicians are in a minority among honors deans and directors, and while many, if not most, of the student posters at the NCHC annual conferences demonstrate that honors students are engaged in undergraduate research in STEM disciplines (Science, Technology, Mathematics, and Engineering) that is of an extremely high quality, relatively few of the session presentations address issues in STEM education and the integration of science and mathematics into multi-disciplinary honors courses.

Perhaps the most distressing issue with mathematical and scientific illiteracy is that people often do not see it as a negative, and in some instances people actually view it as a virtue.[4] While most people would be appalled when individuals confessed that they could not read or write beyond the third grade level, claiming to have difficulty balancing a check book or understanding a relatively simple scientific concept like momentum, until of course one encounters the effects directly in massive loan burdens or a car crash, seems to be fine. In an overwhelmingly technical world where continued economic strength and growth require scientific and technological innovation, a scientifically illiterate population ultimately becomes a liability to the economic health of the country.[5]

Honors education has always taken a lead in developing new approaches to education. In science education this leadership is sorely needed. Science educators must bring to life in the classroom and laboratories the elements of investigation that make possible the effective and legitimate pursuit of new knowledge and new understandings of established science. Students deserve no less than the best educational opportunities to master scientific thought. To that end, the Science and Mathematics Committee of NCHC began a process to collect and publish a monograph of strategies for teaching science in honors education settings with the hope of bridging the cultural divide.

The Science and Mathematics Committee identified the need for a dialog concerning strategies for teaching science in honors curricula. The need arose in response to a number of forces, some internal to honors and others external, including but not limited to the discomfort many liberal arts programs have with incorporating principles of science, the need to meet core curricula standards, the explosion of consumer-based science, and the need for science literacy. In addition, political processes require persons with non-science backgrounds to take responsibility for policy decisions based in science. Complicating these identified needs is the background dialog on the nature of science, scientific evidence, and problem solving driven primarily from outside the sciences by groups with essentially anti-science agenda. Honors students and honors educators find themselves faced with these issues in curricular settings and in general societal environments.

Responding to these imperatives, the Science and Mathematics Committee developed a series of panels for presentation at the 2006 NCHC Conference in Philadelphia. These sessions included curricular strategies that encouraged student civic engagement incorporating scientific concepts. They suggested interdisciplinary approaches to integrating science in general honors courses and ways to emphasize communication and technology in science courses. One panel examined critical thinking and thinking scientifically and argued from a cognitive perspective how students can differentiate science and pseudoscience.

Honors educators from the natural sciences, mathematics, social sciences, and applied sciences have pooled their curricular expertise to bring new approaches and innovative practices to issues affecting science education. The editors hope that these efforts will initiate a new dialog on science education strategies that will be effective in developing scholastic skills in young adults and in regaining the trust and support of the public. This monograph is divided into five sections describing strategies for teaching science in honors to science and non-science students. It describes these strategies through courses, interdisciplinary curricula, and engagement of the science honors student in dialog with society.

In the introductory section, "What is Science in Honors?" educators discuss the students and their thinking processes. Keith Garbutt's "One Size Does Not Fit All" describes the interaction between student types as well as the types of science education in honors. He identifies active teaching as essential to the honors teaching and learning environment. In "Encouraging Scientific Thinking and Student Development," Ellen B. Buckner discusses the many parameters affecting science education and the process of learning. She argues that through inquiry the student can develop the skills and agility to reason scientifically. Paul Mussleman and Buckner describe a partnership between a librarian and honors educator to increase information literacy. When students do not have the skills to access scholarly literature, the wealth of collected scientific knowledge will never be part of an honors education.

Section II, Science and Society, offers an understanding of science education in the context of society. In "SENCER: Honors Science for All Honors Students," Mariah Birgen describes Science Education for New Civic Engagement and Responsibilities (SENCER), a national program of courses that engages students in public issues based in science. The ideals and methods of SENCER offer a novel approach to science education that has great promise for honors students. In "Philosophy in the Service of Science," Thi Lam explores the evolution-intelligent design controversy as a capstone experience in an introductory philosophy course. Through debate students marshal evidence and hone their argumentative and critical-thinking skills. In "Recovering Controversy," Richard England argues that in the evolution-intelligent design debate, including the context of the positions reveals that the two sides are not equally balanced. Finally, in discussing "Science, Power and Diversity," Bonnie K. Baxter and Bridget M. Newell introduce themselves, their backgrounds and passion, to encourage discussion of the historical context and the dynamics of the researcher as influencing science.

In Section III, the authors describe curricula for non-science students. Bradley R. Newcomer queries: "Where Have We Gone Wrong?" He explores active and passive learning and presents strategies for increasing active inquiry. He addresses important issues in science education: philosophy, content and delivery, and assessment. Minerva Cordero, Theresa Jorgensen, and Barbara A. Shipman's "Engaging the Honors Student in Lower-Division Mathematics" discusses overall honors curriculum options in mathematics at the lower level as well as specific pedagogy for lower-division honors courses in mathematics. For those who consider mathematics the unknown territory, these explanations are encouraging. They argue for students taking ownership of mathematics.

In "Statistics in Honors: Teaching Students to Separate Truth from 'Damned Lies,'" Lisa W. Kay describes efforts to integrate statistics and political science. She provides numerous examples of texts and classroom strategies that encourage quantitative literacy. Students complete projects that combine statistics dealing with government and political science. They locate examples in popular literature and debate controversies using statistical analysis as well as conceptual understanding. She concludes with guidelines for statistical education including using real data, active learning, and technology. Joe L March discusses the overall commitment to the ideal of engaged education for freshmen chemistry students in "Is Honors General Chemistry Simply More Quantum Mechanics?" He suggests a range of honors chemistry laboratory experiences from reordering parts of research papers to creating experiments. His techniques engage the student's creativity while balancing the fundamentals.

Section IV considers strategies for providing honors experience to science majors. In "Communicating Science: An Approach to Teaching Technical Communication," Cynthia Ryan, Michele Gould, and Diane C. Tucker emphasize the relationship between scientific inquiry and communication. They offer numerous examples of scientific writing as a mechanism for strengthening scientific thinking. In their second essay on mathematics, Cordero, Jorgensen, and Shipman present strategies, including honors contracts, specific courses, and independent study projects, for pursuing an honors thesis in mathematics. Finally in this section, Michael Doran discusses how the honors thesis process can dovetail effectively with accreditation standards for engineering and computing.

Section V explores the concept of interdisciplinary education. In "Interdisciplinary Science Curricula in Honors," Mullins describes two courses on science themes that form the core of a university honors program. One course engages the "mythology" of the grand narrations explaining human existence; the other course undertakes an ambitious exploration of the environment. In "The Science of Humor," Michael K. Cundall, Jr., argues for engaging honors students through a popular topic common to experience. The interdisciplinary format allows biology, neuroscience, philosophy, and social science to contribute to student understanding. When taught by an interdisciplinary team, students may also see the ways disciplines can and do interact. Kevin M. Williams challenges students and faculty to see correlations between disciplines in "An Interdisciplinary Understanding of a Disease." The students investigate biochemical, physiological, and clinical aspects of a disease and post their contributions and research results for these course projects via a "wiki" technology.

Finally, Section VI concludes with a toolkit for examining science in relation to society and human development. In "Replacing Appearance with Reality," Larry J. Crockett describes how science can give a distinctive emphasis to an honors curriculum. He argues the importance of deconstructing the "P word"—Prove—as the key to understanding reality and science. Garbutt's "Confronting Pseudoscience" describes the often personal challenges and difficulties of distinguishing between truth and falsehood. Students leave the course with tools to evaluate the claims of others both logically and critically. Glenn M. Sanford closes the volume with "Science Education: The Perils of Science Illiteracy, the Promise of Science Education," a balanced discussion of the power both of science and human decision-making in secular and religious contexts. Sanford reasons that society often fails to account for the tentativeness of scientific findings and the role of new data in producing theory change. He gives examples from classroom discussions on current knowledge and future learning.

This monograph addresses the current needs for science education at all levels of higher education. It proceeds from assumptions that the national debate for scientific understanding matters. It explores science in society and strategies for curricular integration in honors. The hope is that this monograph will further the discussion of science and science teaching within honors experiences and will further the engagement of students with the tenets of science applicable to the society and future they face. If it reveals more untapped opportunities and legitimate questions than staid answers and predictable examples, it will have succeeded.

—Ellen B. Buckner and Keith Garbutt
September 2012

Notes

[1]C. P. Snow, *The Two Cultures* (Cambridge, UK: Cambridge University Press, 1998).

[2]Snow gave the 1959 Rede Lecture, an annual public lecture given by the Sir Robert Rede's Lecturer at Cambridge University since 1550. He

was not the first to address the issue of the interaction (or lack thereof) between science and the humanities in this series; in 1882 Matthew Arnold's Rede Lecture was entitled "Science and Literature."

[3]An extreme example may be found on the attacks on the validity of science by some post-modern scholars and the response of scientists such as Alan Sokal with his hoax paper published in *Social Text.* Alan Sokal, "Transgressing the Boundaries: Towards a Transformative Hermeneutics of Quantum Gravity," *Social Text* 46/47 (Summer/Spring 1996): 217–252.

[4]Lawrence M. Krauss, "C.P. Snow in New York," *Scientific American* 301, no. 3 (September 2009): 32.

[5]National Research Council, *Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5* (Washington, D.C.: The National Academies Press, 2010).

SECTION I:
WHAT IS SCIENCE IN HONORS?

Chapter 1

ONE SIZE DOES NOT FIT ALL: SCIENCE AND MATHEMATICS IN HONORS PROGRAMS AND COLLEGES

KEITH GARBUTT

Introduction

The vast majority of today's honors colleges and programs grew out of the liberal arts traditions.[1] As such, the focus of many honors programs has remained within that tradition while the sciences have tended to have a peripheral role. With this history as backdrop, this essay and this volume are aimed primarily at the honors dean or director who has little background in the sciences or science education in the hope they will offer them some important and innovative ideas.

Rightly or wrongly, honors administrators have perceived that science is difficult to include in honors curricula because of its highly specialized and technical nature. Another impediment to including science and math courses in honors curricula may well be the feeling, which is frequently given by faculty as a spurious excuse for not developing honors courses, that such courses are already hard and that developing them into honors courses would make them overly difficult even for the outstanding students normally attracted to such programs. Endorsing this flawed perspective, writes Samuel Schuman, assumes that the only model for honors courses is that of "honors as harder" as opposed to the more appropriate concept of "honors as different," which while it encompasses "honors as harder" is more inclusive in the vein of "enhanced educational opportunities."[2] While the concept of calculus on steroids does have a place, it should certainly not be the only, nor, necessarily, the dominant, model of a science honors course.

Why Should Science Courses Be Included in an Honors Curriculum?

The answer to this question really depends upon the audience at whom the course is aimed. Because the range of majors within most honors programs and colleges is wide and the students are diverse, a one-size-fits-all honors course simply will not work. Convincing the average English major to take a calculus course would be futile. John A. Moore has argued that one of the main benefits of any science course should be to develop certain habits of mind: continual questioning or an informed skepticism, the basic skills of critical thinking, and the use of logically constructed hypotheses that are then tested using evidential reasoning.[3] In addition, understanding the importance of tentative solutions and having the ability to handle uncertainty are central to the way in which scientists view the world.[4] Thus honors programs need science classes in which students have the opportunity to learn qualitative and empirical habits of mind associated with science and the skills necessary to become well-rounded citizens.

Content versus Concept

Unfortunately many science courses still require students simply to memorize facts. While the mastery of building blocks is important, it ultimately does a disservice to students if that is all that is delivered or expected. The facts of today will soon become out-of-date in the light of tomorrow's new information. As one's understanding of biological, chemical, and physical systems deepens, so does the basic data on which that understanding is based. Students will be better served if they are required to understand fundamental concepts. Emphasizing concepts teaches students the skills necessary to be able to become self-motivated and lifelong learners in the discipline rather than simply turning them into large repositories of facts, the knowledge and relevance of which will slowly decay.[5]

Of course, the need to teach the facts in science cannot be completely disregarded. One of the principle reasons to place non-scientists into the scientific classroom is so that they will have the basic background information needed to understand complex issues, such as stem cell research, evolution, and abortion, that require a deep understanding of concepts from the biological sciences. Students need the experience of constructing hypotheses and testing them through experiments in a laboratory.[6] By engaging in this process, they will acquire cognitive tools that will benefit them later. It should be clear however, that the content of the course should have direct relevance to the students taking the course. Watered-down major's curricula for non-majors, which appears to be a common practice in the sciences if one looks at text book offerings, may be more likely to turn students away from science than engage them. While the habits of mind associated with quantitative reasoning are important, they are not sufficient reason for excessively technical, non-applied content that runs the risk of becoming a "Saber-Tooth Curriculum."[7]

In many ways, an honors course should provide an example of college education at its best. In the sciences, the most effective courses, honors or not, are based on a philosophy and approach that "involves active learning strategies to engage students in the process of science and teaching methods that have been systematically tested and shown to reach diverse students."[8] Known as "Scientific Teaching,"[9] after the April 2004 *Science* paper that laid out its basic precepts, this pedagogy is clearly different from the traditional pile-it-on approach that many associate, however inaccurately, with science, math, and honors education. Even in instances in which an increased workload might be justified, the course should be designed with clear, substantive learning objectives that can be assessed appropriately.[10] Halloun and Hestenes' (1985) now classic work illustrated that even students who could perform well on tests, usually using a "plug and chug" strategy,[11] still did not grasp the underlying concepts, particularly when the concepts were counter to their worldviews. Appropriate assessment, therefore, is critical to student success.

Who Are Honors Students and Whom Do They Wish to Become?

The answer to the first part of the question is relatively easy: they are highly motivated individuals who represent a true cross section of American society. Who they wish to be is less obvious. Even within the following groups of archetypal students, these archetypes are not static in any way. It is quite possible, and in fact probable, that any given student will actually partake in one or all of these archetypes at some point in his or her career. One might argue then that a course that combines elements of all these approaches would be an appropriate choice, but this may inevitably lead to the creation of a poorly fitting one-size-fits-all course that serves no one well.

The Highly Trained Professional

Highly trained professional are the students with the potential to be an outstanding practitioner in science, engineering, or mathematics. These students require an extremely deep understanding of both the concepts and the content of the scientific disciplines. These students will benefit most from the calculus-on-steroids model. Courses that are discipline specific and usually aimed toward advanced students can be an extremely important and even a defining experience for these students. In a recent exit interview, a graduating biology student commented on an honors chemistry class that she had taken as a first-year student. She felt that this was the first course that had ever been truly challenging to her, but with the support of an outstanding professor, she ultimately achieved an understanding of chemistry concepts that she initially believed she could not attain. This heavily lab-based course certainly conforms to the ideas of scientific teaching. The student's comments are similar to those that Bain suggests are indicative of transformative teachers.[12] Experiences like this one are important in the development of trained professionals because they build the self-confidence necessary for success. For this type of student, however, it could be argued that the best possible experience would be undergraduate research culminating in an honors thesis. The impact of undergraduate research experience cannot be underestimated. Since the Boyer Commission report in 1998,[13] research has shown that in terms of both motivating students to enter research careers and preparing them for those careers, undergraduate research experiences are crucial. They benefit not only the student but also the research lab they work in.[14]

The Moral Scientist or Engineer

In addition to discipline-specific courses, the moral scientist or engineer will also need to take courses that integrate philosophy and ethics. Having students rely on humanities courses for these components is not sufficient since those courses are often disconnected from the scientific process. Given the sorts of decisions that modern scientists must make, Seebauer and Barry recognize that students need to be well grounded in notions of moral and ethical responsibility.[15] Whether looking at concepts of academic freedom and academic dishonesty or at moral decisions concerning the type of research in which they are involved, science students must fully grasp the basic concepts and choices.

Courses for this type of student should consider and debate the current controversial areas where science, mathematics, and engineering all come into play. These classes are often referred to as honors add-on classes. In this model, students may take a class in the natural sciences as well as a separate section on the issues arising out of the regular course material. For example, an add-on biology class may look more deeply at the biology behind stem cell research, reproductive technologies, and environmental issues and have debates on their ethical and political implications. For science, technology, engineering, and mathematics (STEM) disciplines, students might also consider the implications of working on weapons research: What are the ethical issues for an individual considering a career in this area? Are there limits beyond which one is not willing to go? The purpose of these courses is for the students to develop a reflective mode when thinking about science and its consequences, to view it outside the straightjacket of the scientific discipline or the search for knowledge, and to address for themselves the broader implications. The crucial outcome of these types of courses is not the final choice that the students make but that they have chosen a position based on serious and informed consideration.

The Critical Thinker

The critical thinker is in many ways the gold standard of all liberal education: the individual who can bring an incisive logical mind to any problem. Science, with its emphasis on hypothesis testing and evidence-based logic, provides excellent tools for the critical thinker. In addition, science honors courses help students understand that not all knowledge is currently known and that areas of uncertainty exist, areas in which intermediate or temporary hypotheses are, at best, only tentative and will be revised with new discoveries.

An honors science curriculum may have great impact on the critical thinker. Because critical thinking is in itself a basic skill, it can be taught at a series of levels. Teaching critical-thinking skills in courses where the level of scientific literacy is not particularly high is possible because individuals can apply the methodology of science without having to master advanced content.

A model course for the critical thinker is "Confronting Pseudoscience," which is described in Chapter 19. This course is open to all majors and introduces students to the basic principles of critical thinking, evidential reasoning, and analysis of authority. Using ideas that Carl Sagan[16] calls tools for the "detection of baloney," students apply the scientific method to ideas and issues that are purported to be scientific but prove otherwise on close examination by using the tools of critical thinking. Such a course enables students to develop the scientific habits of mind in a less-threatening manner than a conventional discipline-based course. It might be argued that unless critical thinking and the scientific method are embedded and explicit in discipline-based courses, then courses that explicitly teach critical thinking will be more beneficial to students than standard science courses. Students in these courses ultimately acquire life skills that will enable them to examine claims in the media with skeptical and critical eyes.

The Educated Citizen

The notion of the educated citizen hearkens back to the foundation of the first universities in America and is related to the Jeffersonian ideal of a polity capable of making appropriate choices.[17] Courses requiring students to address the controversial issues in science are an excellent way to produce educated citizens.

Part of being an educated citizen is having the ability to analyze and evaluate information and to express that information in one's own words. Thus courses with a significant communication component can be especially important. While some academics (perhaps a rapidly declining number) often view communication as predominantly the paper or perhaps written comments on student's work or lecture, students certainly do not communicate solely in this fashion. Blogs, instant and text messengers, Twitter feeds, Facebook posts, and videos (YouTube) are all means of rapid, indeed sometimes viral, communication. Educators must be aware of these modes of communication and consider integrating some of them into courses because they may facilitate learning particularly for students who have learning styles that do not mesh well with traditional forms of delivery, and because events in the spring of 2011 showed, they can be very powerful tools indeed.[18] By practicing communication skills in a variety of modalities, students will learn how to communicate effectively and persuasively on issues in the modern world. An example of such a course is "Communicating Environmental Messages," created by James B. McGraw of West Virginia University. West Virginia University Honors College students embedded in McGraw's course, which is a required second-year course for biology majors, engage in a discourse on communication in which he introduces them to using various multimedia methods. McGraw requires students to communicate complex ideas in a totally visual medium. For example, the students may construct non-traditional communication pieces such as music videos about environmental issues. McGraw has recently redesigned his course to require that students create a multimedia public-service announcement on issues in biology.[19]

Conclusion

Obviously, one universal model for a science course will not account for all societal, institutional, or student needs. This observation underscores the obligation of educators to reflect on the nature of their courses and the particular needs of their students. While this point may be rather obvious, the topic does allow for reflection upon the reasons for incorporating science into honors programs and colleges and to understand they are both numerous and varied. The methodologies and techniques for presenting these courses vary as well, as this volume illustrates.

Honors colleges and programs provide an environment for educational experimentation, innovation, and development. Honors directors should encourage faculty members, particularly those in the sciences, to take the philosophy of "Scientific Teaching"[20] to heart by being as serious about scholarship pertaining to pedagogy and teaching as they are about scientific research. Faculty members who pursue this strategy will provide the type of environment where talented students can prosper and develop the skills necessary for future success. Of course, all educators should keep abreast of developments in pedagogy in designing these courses.[21] Instructors must also be clear about the learning outcomes students should achieve from these courses and be prepared to measure them through appropriate assessment methodologies.

The analytical tools of science can be used across disciplines and experiences and are part of the skills that should be nurtured by the tradition of liberal education, which is the very essence of honors education.[22]

Bibliography

Bain, Ken. *What the Best College Teachers Do.* Cambridge: Harvard University Press, 2004.

Ben-Ari, Moti. *Just a Theory: Exploring the Nature of Science.* Amherst, NY: Prometheus Books, 2005.

Boyer Commission on Undergraduate Education in the Research University, Reinventing Undergraduate Education: A Blueprint for America's Research Universities. Pub. Boyer Commission on Educating Undergraduates in the Research University, Room 310, Administration Bldg., State University of New York, Stony Brook, NY 11794-0701 1998.

Brown. Earl B. "Level Differentiation in the United States, Part 1," *The National Honors Report* 22, no. 2 (Summer 2001): 48–54.

Creath, Richard, and Jane Maienschein, eds. *Biology and Epistemology.* New York: Cambridge University Press, 2000.

Ebert-May, Diane, Janet Batzli, and Heejun Lim. "Disciplinary Research Strategies for Assessment of Learning" *BioScience* 53, no. 12 (December 2003): 1221–1228.

Handelsman, Jo, Sarah M. Laufer, and Christine Pfund. *Scientific Teaching*. New York: W.H. Freeman & Company, 2006.

Handelsman, Jo, Diane Ebert-May, Robert Beichner, Peter Bruns, Amy Chang, Robert DeHaan, Jim Gentile, Sarah Lauffer, James Stewart, Shirley M. Tilghman, and William B. Wood. "Scientific Teaching," *Science* 304, no. 5670 (April 2004): 521–522.

Handelsman, Jo. "Not Science Fiction: Undergraduates Productive in Research." *DNA and Cell Biology* 29, no. 9 (2010): 465.

Halloun, Ibrahim Abou, and David Hestenes. "Common Sense Concepts about Motion," *American Journal of Physics* 53, no. 11 (1985): 1056–1065.

—. "The Initial Knowledge State of College Physics Students." *American Journal of Physics* 53, no. 11 (1985): 1043–1055.

Klionsky, D.J. "Talking Biology: Learning Outside the Book—and the Lecture." *Cell Biology Education* 3 (Winter 2004): 202–211. Part of "Points of View: Lectures: Can't Learn with Them, Can't Learn without Them."

Mintzes, Joel J., James H. Wandersee, and Joseph D. Novak, eds. *Teaching Science for Understanding: A Human Constructivist View.* Burlington, MA: Academic Press, 2005.

Moore, John A. *Science as a Way of Knowing: The Foundations of Modern Biology*. Cambridge: Harvard University Press, 1993.

Padover, Saul K. *Thomas Jefferson on Democracy*. New York: Appleton-Century Company, Inc., 1939.

Peddiwell, J. Abner. *Saber-Tooth Curriculum: Including Other Lectures in the History of Paleolithic Education.* New York: McGraw-Hill, 1939.

Sagan, Carl. "The Fine Art of Baloney Detection." *The Demon-Haunted World: Science as a Candle in the Dark.* Carl Sagan and Ann Druyan, eds. New York: Ballantine Books, 1997.

Schuman, Samuel *Beginning in Honors, A Handbook,* 4th ed., Lincoln NE: National Collegiate Honors Council, 2006.

Seebauer, Edmund G., and Robert L. Barry. *Fundamentals of Ethics for Scientists and Engineers.* New York: Oxford University Press, 2000.

Notes

[1]Earl B. Brown, "Level Differentiation in the United States, Part 1," *The National Honors Report* 22, no. 2 (Summer 2001): 48–54.

[2]Samuel Schuman, *Beginning in Honors, A Handbook,* 4th ed., Lincoln NE: National Collegiate Honors Council, 2006. Described in Samuel Schuman's invaluable guide to new honors deans and directors.

[3]John A. Moore, *Science as a Way of Knowing: The Foundations of Modern Biology.* (Cambridge: Harvard University Press, 1993).

[4]Richard Creath and Jane Maienschein, eds., *Biology and Epistemology.* (Cambridge: Harvard University Press, 2000). The ability to deal with tentative solutions and the concept of uncertainty are among the key indicators of a well-developed intellect. This aspect of the sciences is, however, unfortunately missing from many introductory science classes, leading to major misunderstanding on the part of the general public about what science actually is since many people's experiences with science is as a catalog of known facts.

[5]Jo Handelsman, Sarah M. Laufer, and Christine Pfund, *Scientific Teaching.* (New York: W.H. Freeman & Company, 2006). This work has excellent examples of how to break the cycle of memorizing facts and how to promote active learning even in large classrooms. D. J. Klionsky, "Talking Biology: Learning Outside the Book—and the Lecture," *Cell Biology Education* 3 (Winter 2004): 202–211. Part of "Points of View: Lectures: Can't Learn with Them, Can't Learn without Them."

[6]Joel J. Mintzes, James H. Wandersee, and Joseph D. Novak, eds. *Teaching Science for Understanding: A Human Constructivist View* (Academic Press, 2004).

[7]J. Abner Peddiwell's classic work: *Saber-Tooth Curriculum: Including Other Lectures in the History of Paleolithic Education* (NY: McGraw-Hill, 1939). In this text the cavemen continue to teach the classical Saber-Tooth Curriculum even after the saber-tooth are extinct, justifying their curriculum by claiming it taught important habits of mind.

[8]Jo Handelsman, Diane Ebert-May, Robert Beichner, Peter Bruns, Amy Chang, Robert DeHaan, Jim Gentile, Sarah Laufer, James Stewart, Shirley M. Tilghman, and William B. Wood, "Scientific Teaching," *Science* 304, no. 5 670 (April 2004): 521–522. It should be noted that this group of authors includes the then Head of Grants and Funding for the Howard Hughes Medical Institute, HHMI fellows, and the President of Princeton University.

[9]The development and expansion of "Scientific Teaching" continues with yearly workshops funded by HHMI and the National Academies of Science and more recently NSF-funded regional workshops such as that run at West Virginia University by Dr. Michelle Withers.

[10]Diane Ebert-May, Janet Batzli, and Heejun Lim, "Disciplinary Research Strategies for Assessment of Learning," *BioScience* 53, no. 12 (December 2003): 1221–1228

[11]Ibrahim Abou Halloun and David Hestenes, "The Initial Knowledge State of College Physics Students," *American Journal of*

Physics 53, no. 11 (1985): 1043–1055. And Ibrahim Abou Halloun and David Hestenes, “Common Sense Concepts about Motion,” *American Journal of Physics* 53, no. 11 (1985): 1056–1065.

[12]Ken Bain, *What the Best College Teachers Do* (Cambridge: Harvard University Press, 2004).

[13]Reinventing Undergraduate Education: A Blueprint for America’s Research Universities. Byer Commission 1998.

[14]See editorial by Jo Handelsman in “Not Science Fiction: Undergraduates Productive in Research,” *DNA and Cell Biology* 29, no. 9 (2010): 465.

[15]Edmund G. Seebauer and Robert L. Barry, *Fundamentals of Ethics for Scientists and Engineers* (Oxford: Oxford University Press, 2000).

[16]Carl Sagan, “The Fine Art of Baloney Detection,” in *The Demon-Haunted World: Science as a Candle in the Dark.* Carl Sagan and Ann Druyan, eds. (NY: Ballantine Books, 1997). This book, which seems even more germane than when it was first published, provides a clear warning about the impact of scientific illiteracy on society while at the same time providing a clear introduction to critical thinking.

[17]Saul K. Padover, *Thomas Jefferson on Democracy* (New York: Appleton-Century Company, Inc., 1939). Jefferson said, “whenever the people are well-informed, they can be trusted with their own government. . . .”

[18]The positive and negative use of rapid text messaging was seen in the events of “The Arab Spring” and the London riots of 2011.

[19]To see the results of the students work in Dr. McGraw’s class, visit <http://www.youtube.com/watch?v=DxGiv3c0TCQ>.

[20]Jo Handelsman, et al., “Scientific Teaching,” *Science* 304, no. 5670 (April 2004).

[21]Jo Handelsman, et al. “Scientific Teaching,” *Science* 304, no. 5670 (April 2004).

[22]It is fascinating to see projects such as the Southern History Project at the University of Virginia <http://www.vcdh.virginia.edu/SHD/about_SHD.html> where historians are beginning to apply data collection, databases, and data analysis methodologies to examine hypotheses in history, adopting the methods that have been used in science for well over a century.

Chapter 2

ENCOURAGING SCIENTIFIC THINKING AND STUDENT DEVELOPMENT

Ellen B. Buckner

Introduction

Honors students are certainly multidimensional people with broadly defined interests, but they are not necessarily interested in becoming scientists. Nevertheless, honors students must be scholars of science who are capable of employing scientific thinking and accurately representing science in societal contexts. Science has become increasingly difficult especially because of the complexity of topics, a heavily financed research industry, and threats to basic definitions of science. These characteristics make the understanding of scientific progress inaccessible to many. Yet science belongs to all, and in most aspects of daily life, from the unpredictability of weather to the stability of political power, science is an operative force. Principles of science govern the natural environment, the creation of humans, and aspects of human relationships themselves. Humans have historically viewed science as a companion to be understood and employed in service to self and to others. With increasing technological sophistication and the introduction of controversy, the study of science has become labored and hard to master. Science teachers and students are forced to defend the basis of their knowledge. Teachers required to meet educational testing benchmarks may not have the interest or administrative support to encourage students' natural curiosity and develop in them the patterns of scientific thinking essential to understanding the natural world. Disclaimers and political positions have taken the place of well understood and appropriately applied scientific principles for the public good.[1] To many people, scientists have become increasingly distant and unapproachable.

Why is science so hard? Why do students have such difficulty with science? Why does science trigger the avoidance or survivor instinct? Honors science educators must strive to break through students' resistance to provide opportunities for learning and development. Science educators must help students recapture the joy of discovering science.

Modes of Reasoning and Measurement

Today, scientific methods include many approaches that scientists once considered outside the mainstream. Scientists employ both deductive and inductive reasoning to make inferences. Deductive studies are characterized by well-developed hypotheses, frameworks for analysis, quantitative measures, and conclusions based on theory and observation. Inductive studies are characterized by empirical observations (concrete or data-based) from which theoretical propositions are developed. Both methods hold value for understanding scientific processes and have historically been used in scientific investigation.

Human studies increasingly draw on multiple processes to define and examine phenomena of interest. Qualitative methods involve interviews and focus groups to understand perceptions, and the analysis of the transcripts allows processes and themes to emerge. Prospective and retrospective studies of people's perceptions can inform science but often provide divergent descriptions. The purposes and results of those studies must be framed in a temporal order to be science. Post-hoc analyses cannot supplant prospective designs any more than Monday-morning quarterbacking can alter the plays of Sunday's games. Learning combines science with human understanding of control and decision making.

Both qualitative and quantitative measures are accepted in scientific settings. From chemical determination of an unknown element to the documentation of a person's experiences through interviews, qualitative assessment is essential to define the characteristics of science. Qualitative approaches are particularly useful when the phenomenon is not well understood or has not been the subject of investigation. The accuracy of quantitative measures cannot be assumed without establishing adequate standards of validity, reliability, calibration, and application. Skills for the science student to master include demonstrating competence in the techniques and procedures of the measurement device—whether that device is a thermal sensor, cardiac monitor, or an interview.

Science is creative and accountable. Combining these efforts keeps science education honest, progressive, and applicable in today's complex world. The task of science educators, especially those engaged in honors education, is opening the world of science exploration to students in ways that build their understanding as well as their participation in science-related activities. As lifelong learners and engaged members of society, honors students need the critical ability to understand science and the processes of science.

Honors students should graduate not as scientists but as science scholars using the language of science to understand its meaning and to create meaning within their own environment. This is no small task. It includes recognition of the sources of observation and the communication of observations in ways that can be comprehended by others from diverse backgrounds and experiences. It requires the weighing of interpretation in conjunction with human values. Educators must not only overcome any aversions to science but also engage students in meaningful scientific lessons that underscore the accomplishments of science. Whether the lesson is why a cake or soufflé rises or why clean water transforms the health of a village, the lessons must register with students as scientific thinking. The goal of this essay is to suggest ways and approaches to stimulate students' development of scientific thinking as well as to assist students in realizing the power and ownership of science needed by all.

Pedagogy of Inquiry-Based Learning

Primary Source Data in Science

Teaching science in honors requires two basic ingredients: content and process. Although the content that students must acquire is substantial, this discussion will focus on the process of learning in science. This process needs improvement at every level. Inquiry-based science learning gives students the tools to create meaningful studies as they use the language and tools of science to view the earth through the eyes of science. Students participating in inquiry-based science at undergraduate levels are not established scientists but rather are science scholars using the language of science to understand its meaning. Students then can begin to create meaning within their own environment. The single-most important concept in inquiry-based learning is recognition of primary source data. Students must rely on primary source data in appraising research done by others or initiating inquiry-based activities of their own. By reading original research, the students can come to know a subject and recognize how the subject is known. By doing original, though limited, research, the students experience the underlying processes of making assumptions and recognizing the limitations and power of conclusions. The most elemental understanding of primary sources supports student development across multiple domains.

Students may express an underlying assumption that all science has, of course, been properly developed and linkages well established.

Seasoned scientists know that is not always the case. A series of published student quotations comically reveal their naiveté on this notion. Rambur described the difficulty of students who struggled woefully with concepts of primary sources.[2] The following true confessions reveal the typical student plight:

> "All the textbooks said the same thing so I expected to find a lot of primary sources, but I can't find any."
>
> "Most of the references cite an earlier source. Eventually it converges to one person's statement, but it wasn't based on research. How can they do that?"
>
> "I can't write this paper. All the sources say something different!"

Each of these passages can be teachable moments for astute honors educators as they encourage students to probe further, identify the assumptions, raise counter arguments and identify testable hypotheses that could provide evidence to support or refute the finding. Students can be taught to question textbooks to find the original research underlying a conclusion or principle. They can be encouraged to focus on the time and place of data collection and the limits of the technology employed. Every question begets other questions with assurance and fact emerging as rare qualities indeed. Students who begin to recognize contradictions are at the perfect place cognitively for understanding why and how scientists know what they know and do not yet know. This awareness is critical for science understanding.

The communication of science in a logical argument strengthens scientific thinking and application through the language of science. As with any language the vocabulary, relationships, and building of argument are keys to linguistic analysis, understanding, and persuasion. These skills of language and science are inextricably entwined. Transforming the honors student to science scholar requires a foundational understanding of the origin and application of primary source data. Developing this awareness will require meaningful assignments and constant engagement by the honors educator to link the disbelief of a student's initial encounter with the reality of the phenomenon and its developed knowledge base. Then and only then can meaningful discussions of science and its significance be initiated.

Teaching Strategies for Inquiry

Several authors have suggested strategies for encouraging the scholarship of inquiry.[3] One of these, sensitizing students to research-related ideas, can begin as historical research to find the original data answering a scientific question. With access to literature via the Internet, students can easily scrutinize original publications.

An example of the process of conducting historical research to find the original reference began when I was a student and encountered the prohibition of administering a particular antibiotic, chloramphenicol, to premature neonates. The pharmacology textbook reported that it caused "gray baby syndrome," a toxic and life-threatening effect. I dutifully memorized the fact and the prohibition. Years later I was asked to speak on the topic, and I located the original case reports and research done decades earlier. Only then did I really see firsthand the state of pharmacology knowledge then and now. When I read reports in that era that documented the syndrome and resulted in stopping the use of the medication in that age group, I began to see the way science investigation informed the safety of drug therapy today. It also contributed to a then-nascent research enterprise now dedicated to creating new drugs with fewer toxicities and more effectiveness. The link over the decades was the language of science through peer-reviewed publication. This kind of study is available to students if they are assigned the task of locating and relating historical scientific discoveries to the textbook principles of today. Furthermore, a detective-like investigative spirit of finding the lost data can be effective in engaging the novice science student.

Individual exploration is one format for student learning, but another gaining increasing endorsement in educational circles is that of collaborative learning. Students can work together using online collaborative tools such as a Wiki, role play a group activity such as developing a biotechnology company, or develop an inquiry-based science project as an active-learning experience. (See the suggested assignments and references at the end of this essay.) Students who are unseasoned in the strategies and learning techniques of group activities may require coaching from faculty, especially when the strains of collaboration may be keenly felt by the strong individualists who often come to honors.

The best method of stimulating collaborative learning may not be group projects, however, but students reporting to the group on their individual projects through a seminar format. This is especially effective for honors students completing thesis work. Students like to second-guess one another's conclusions, find more worth in another's work, seek to understand one another's ideas, and engage in active discussion of the ideas. The experiences are also part of the process of science. Students often leave such seminar presentations discussing ways they can help or collaborate with other students on their projects.

Sharing the Language of Science

Another teaching strategy for science education in honors is setting up an environment in which students field questions from one another. These can be formal paper or poster presentations or even less formal presentations during a seminar session. Students enhance their analytic skills when they assimilate the material and context and then pose a relevant query. Student presenters must then understand, translate, and choose from a range of options from technical to conceptual to answer questions in ways that relate and create a bond. Both scientific and communication skills are embedded in fielding questions about each other's work. Seminars emphasizing individual inquiry provide numerous opportunities for developing the language of research and verbal and written communication. Debates where opposing views are presented using evidence-based literature can be a way of responding to questions or differences in the interpretation of evidence. All of these strategies develop the ability of questioners and responders to accurately define the question and answer.

Relationships are important in building an understanding and appreciation of science. Faculty and clinician mentorships provide a window into the ongoing use and application of research and inquiry. Students see the larger context and can ask questions about relevance, history, and future trends. Students see the relationships among larger ongoing works and their own ideas. With a good mentor, the student can gain both confidence and a structural view of scholarship. The science scholar who can effectively question has the ability to gain new knowledge over a lifetime and bring relevant skills and preparation to any decision. Students can, for example, detail the growth, difficulties and outcomes of such student-mentor relationships in reflective journals.

Assignments, projects, or reflective journals can nurture inquiry-based learning. Inquiry-based honors science education is highly effective when students complete an honors thesis or research project, but inquiry may be undertaken at any level. In an inquiry-based program, teachers encourage students to read research, to look at and access information databases, and to develop information literacy. Through the different skills students acquire in inquiry-based teaching and learning, educators engage the students actively, encourage their responses, and strengthen their autonomy so that they leave the interaction with a sense of why science matters to them as individuals and as members of society.

Developmental Issues and Pedagogy

Critical thinking progresses in developmental stages.[4] As freshmen and sophomores, most students are just beginning to acquire basic scientific critical-thinking abilities. At this level of age and experience, they may have only minimal awareness of how they make their own judgments, how they make observations, or how they describe what they experience and understand. At higher levels, students possess these basic skills and also recognize their own need for further learning. They can identify when their routines are not adequate and when change is needed. When these students are fully engaged, they have the potential to expand and hone their abilities to think critically.

Science pedagogy both influences and is influenced by the developmental level of students. With increasing levels of development comes the ability to apply and synthesize knowledge. Students gain a creative sense of how, when, and why to apply theories and processes in differing settings. Group-based collaborative science experiences encourage development of interpersonal skills as the students gain insight into empowering others and collaborating on a shared goal. Through collaborative learning, the relative isolation often ascribed to science becomes a shared enterprise with common ground rules and tenets. The results, too, are shared and can be the subject of analysis that underscores the social nature of science. In an analysis of levels of cognitive development, Perry lists the early stages of cognitive development. The first stage is dualism, viewing issues as right or wrong.[5] In this stage students often seek concrete answers without recognizing the underlying forces at work. Part of the scientific approach is deciphering ambiguity and reasoning through competing questions and hypotheses. This form of scientific thinking is particularly difficult for beginning students and may give rise to defensive responses based on prior conceptions. The educator's role may first be to establish the communication and trust to allow students to formulate honest questions. The second stage is that of multiplicity or the ability to accept diverse opinions but with truth personalized and subjective. Through continued learning, these budding science scholars may accept diverse conceptualizations and empirical findings but still lean on their own interpretation for meaning. These stages are part of the students' progression, but, if permanent, could reduce the study of science to hollow or egocentric arguments. As the students move from passive to active learners, the foundations of science become the underpinnings of a growing articulation with scholarship. Primary source data and reasoning replace reliance on seeming facts. As the students enter the higher stages that Perry describes, they demonstrate relativism and formulate opinions and values in the context of their learning. The students redefine science as functional, instrumental toward substantive ends, and solidly falling within the domain of human capacity. Empathy, doubt, and objectivity become the hallmarks of this transition.

In Perry's fourth stage, commitment-in-relativism, individuals can make personal choices and are capable of integrated knowledge. The learners are part of that process and have the capacity to listen with responsibility to self and others. This concept of honors student as science scholars is not focused on the scientist in the laboratory who is creating new knowledge but on the student as societal being with responsibility and insight. In teaching science, educators must include the interpretation and application of science in a human context. This stage is the goal of science pedagogy. Thus, as methods, strategies, seminars, and assignments proceed, the goal is not only the clear comprehension of the known content but the engagement of the honors student in the process of personal development as a scholar. The learning of science occurs in the developmental context of human growth. Educators must adapt teaching strategies to the learner's progress. Educators establish the formal teaching-learning environment and build in informal processes to engage the learner. Therefore, the educator's recognition of student growth is essential to effectiveness from the earliest stages of resistance to the later stages of metacognition.

Promoting Learning in the Cognitive and Affective Domains

In order to engage the science scholar effectively, educators must build positive responses in the affective or emotional domain. This process includes building confidence and strengthening autonomy. Haffer and Raingruber show the crippling effects of diminished confidence on learning.[6] When confidence decreases, the student becomes overwhelmed by inexperience, perceives peers more capable, lacks the confidence to ask questions, focuses on potential harm and total responsibility, and becomes disorganized or scattered. With increased confidence the student has the energy and cohesiveness to draw strength from others' experiences, recognize comparability to peers, discover power in questioning, experience shared responsibility, and focus under stress. The challenge for the educator is to change the pedagogy to develop and produce confidence.

Autonomy develops in inquiry-based learning from struggling to define the situational, clinical, or research question. The abstractness of the concepts and interrelationships, the practicality of the question, and its ability to be answered in a known time frame encourage the students' manipulation and real-world analysis of the idea or project. The cited literature, data, and evidence further define it in terms of science.

Krathwohl, Masia, and Bloom describe the stages of educational development in the affective domain with the highest level being that of characterization by the values of the organization or profession.[7] Because science is a mainstay of scholarship, its general mastery is essential for basic literacy. Through the development of active learning of science through inquiry-based projects, the student experiences a firsthand definition of the scientific process. Autonomy can also be strengthened through communicating the results of an inquiry-based activity or project. The experience of communicating findings forms the basis for growth in the affective domain when students present their ideas in the classroom or to other groups. Continuation of this spirit of inquiry can promote enduring patterns of research use and supports lifelong learning. Competence produces knowledgeable consumers of research and productive researchers.[8]

Strategies for Promoting Reasoning Skill and Reflection

Strategies to promote reasoning skills must include opportunities for reflection about content and the learning process itself. Reflection is a strategy to enhance metacognition: thinking about thinking or knowing about knowing. Kuiper and Pesut believe that effective clinical reasoning skills depend on both cognition (critical thinking) and metacognition (reflective thinking).[9] Their literature review identified numerous strategies for promoting reasoning. They found that strategies to stimulate both critical thinking and reflective thinking were linked in the development of clinical reasoning and judgment. They recommended emphasizing reflective thinking when teaching. Such strategies included consideration of context and the situational aspects of clinical practice in multiple disciplines, dialog and discussion, diaries and journaling, guided discussion to develop self-monitoring of feelings and attitudes, and construction of meaning through experiences. The primary window into student growth was observing the students' abilities to explain the basis of their judgments. Students at lower levels were characterized by an absence or minimal awareness of judgments, observations, and descriptions. Students at higher levels recognized the need for further learning and an awareness of situations when their routines for studying were inadequate or in need of change. Kuiper and Pesut found the following teaching strategies critical to developing cognitive growth: a) recognizing students' fear of judgment and evaluation; b) providing community-based experiences; c) fostering confidence and responsibility; d) discouraging premature closure; e) avoiding negative situations that promote helplessness; f) instilling the idea that growth requires valuing experience; g) giving opportunity for structured reflection; h) creating dialog to expose contradiction and conflict; i) making a commitment to expose and confront distortion; j) understanding one's own limitations; k) nurturing commitment; l) gaining insight to resolve contradiction; and m) facilitating the development of clinical reasoning skills and judgment over time and with practice.[10] These strategies, developed in clinical practice settings (medicine, nursing, allied health, or others) can also be transmitted to other hands-on or experiential settings of community service, active engagement with individuals and groups, and study abroad.

In *Knowledge for Healthcare Practice*, Sarah J. Brown described the relationship of reflective thinking about professional practice as essential to the ability to appraise, practice, and formulate a clinical question. She stated that most clinical questions have their origin in the patient-provider encounter or in the clinical thinking of the provider as he or she decides what care to provide. Others are formulated during professional dialog or while examining quality improvement. All originate in the minds of reflective practitioners.[11] Many students seeking professional education and employment beyond the academy sorely need these skills.

Conclusions

Through engagement, encouragement, and a support system for autonomy, honors students can develop competence as scholars of science in an information-rich society. Teaching strategies for both critical thinking and reflective thinking are needed. These strategies can be employed in diverse educational settings and with assignments in varied contexts. Literature-based and experiential research or other means to promote scholarship and inquiry can cause science scholars to develop an awareness of primary source data based on the evidence. Individual and collaborative inquiry-based active-learning experiences not only encourage questioning but also assist the student in developing intellectually and personally. This growth is essential to establishing autonomy as a fully functioning scholar with the ability to contribute meaningfully to a changing society. Strategies that promote cognitive, affective, and metacognitive development strengthen the appreciation and perspective the student brings to lifelong learning. The role of the honors educator in preparing the teaching-learning environment for students' developmental growth as science scholars is a required part of the educational mission.

Assignments and Discussion Questions

1. Have students work in groups to choose a current issue; develop a bibliography on the subject, including less-than-optimal sources; and then weigh the evidence pro and con.
2. Write a position paper advocating a particular policy or approving a new procedure or project that is built on scientific principles. Locate sources and critically appraise those in the position taken. How difficult would it be to persuade others to adopt your position?
3. Develop an inquiry-based proposal. Include rationale, methods, and expected outcomes. Keep the total length relatively brief to conform to the requirements of a funding agency and develop a work plan or timeline for implementation. What are the points of interface with others such as approval bodies, partners, agencies, or sponsors? What parts need to be technical and what parts must be conceptual to gain support?
4. Choose a currently accepted "fact" and trace the knowledge of that fact historically. Was it based on observation or other evidence? Was the data systematically collected or acquired anecdotally? Does it rely on primary source evidence?
5. Differentiate what is known by objective and subjective methods. How do we know what we know?
6. Have students present a data-based report and assign 1 or 2 students to critique the presentation. They may be given the topic in advance or just work from the content presented. Students may be assigned to give a negative or positive critique. The class may use clickers or a show of hands to vote for the best argument.
7. Ask students to reflect on an educational experience in science or mathematics in their youth. How was it positive or negative? What did the students learn at the time? How did they feel at the time?

How did it affect their later learning processes? How does past experience affect their learning processes now?

8. Create a collaborative opportunity in science using online collaboration (Wiki), role play, or group inquiry.

Bibliography

Brown, Sarah J. *Knowledge for Health Care Practice: A Guide to Using Research Evidence.* Philadelphia: W. B. Saunders, 1999.

Callister, Lynn Clark, Gerry Matsumura, and Sandra Lookinland. "Inquirey in Baccalaureate Nursing Education: Fostering Evidence-Based Practice." *Journal of Nursing Education* 44, no. 2 (2005): 59-64.

Dawkins, Richard. "The 'Alabama Insert':A Study in Ingnorance and Dishonesty." *Journal of the Alabama Academy of Science* 68, no. 1 (January 1997).

Haffer, Ann G., and Bonnie J. Raingruber. "Discovering Confidence in Clinical Reasoning and Critical Thinking Development in Baccalaureate Nursing Students." *Journal of Nursing Education* 37, no. 2 (1998): 61-70.

Jacobs, Susan Kaplan, Peri Rosenfeld, and Judith Haber. "Information Literacy as the Foundation for Evidence-based practice in Graduate Nursing Education: A Curriculum-Integrated Approach." *Journal of Professional Nursing* 19, no. 5 (2003): 320-328.

Krathwohl, David R., Bertram B. Masia, and Benjamin Samuel Bloom. *Taxonomy of Education Objectives, the Classification of Educational Goals: Handbook 2, Affective Domain.* New York: D. McKay, 1964.

Kuiper, Ruth Ann, and Daniel J. Pesut. "Promoting Cognitive and Metacognitive Reflective Reasoning Skills in Nursing Practice: Self-Regulated Learning Theory." *Journal of Advanced Nursing* 45, no. 4 (2004): 381-391.

Perry, Jr., William G. *Forms of Intellectual and Ethical Development in the College Years: A Scheme.* New york: Holt, Reinhart and Winston, 1970.

Rambur, Betty. "Fostering Evidence-based Practice in Nursing Education." *Journal of Professional Nursing* 15, no. 5 (1999): 270-274.

Notes

[1]Richard Dawkins, "The 'Alabama Insert': A Study in Ignorance and Dishonesty," *Journal of the Alabama Academy of Science* 68, no.1 (January 1997). Presented as part of the annual meeting of the Alabama Academy of Science and the Franklin Lectures in Science &

Humanities, Auburn University, April 1, 1996. Available online at <http://www.simonyi.ox.ac.uk/dawkins/WorldOfDawkins-archive/Dawkins/Work/Articles/alabama/1996-04-01alabama.shtml>.

[2]Betty Rambur, "Fostering Evidence-based Practice in Nursing Education," *Journal of Professional Nursing* 15, no. 5 (1999): 270–274.

[3]Susan Kaplan Jacobs, Peri Rosenfeld, and Judith Haber, "Information Literacy as the Foundation for Evidence-based Practice in Graduate Nursing Education: A Curriculum-Integrated Approach," *Journal of Professional Nursing* 19, no. 5 (2003): 320–328.

[4]Ruth Anne Kuiper and Daniel J. Pesut, "Promoting Cognitive and Metacognitive Reflective Reasoning Skills in Nursing Practice: Self-Regulated Learning Theory," *Journal of Advanced Nursing* 45, no.4 (2004): 381–391.

[5]William G. Perry, Jr., *Forms of Intellectual and Ethical Development in the College Years: A Scheme* (New York: Holt, Reinhart and Winston, 1970).

[6]Ann G. Haffer and Bonnie J. Raingruber, "Discovering Confidence in Clinical Reasoning and Critical Thinking Development in Baccalaureate Nursing Students," *Journal of Nursing Education* 37, no. 2 (1998): 61–70.

[7]David R. Krathwohl, Bertram B. Masia, and Benjamin Samuel Bloom, *Taxonomy of Education Objectives, the Classification of Educational Goals: Handbook 2, Affective Domain* (New York: D. McKay, 1964).

[8]Lynn Clark Callister, Gerry Matsumura, and Sandra Lookinland, "Inquiry in Baccalaureate Nursing Education: Fostering Evidence-Based Practice," *Journal of Nursing Education* 44, no. 2 (2005): 59–64.

[9]Kuiper and Pesut, "Promoting Cognitive and Metacognitive Reflective Reasoning Skills."

[10]Ibid.

[11]Sarah J. Brown, *Knowledge for Health Care Practice: A Guide to Using Research Evidence* (Philadelphia: W.B. Saunders, 1999).

Chapter 3

INFORMATION LITERACY AS A CO-REQUISITE TO CRITICAL THINKING: A LIBRARIAN AND EDUCATOR PARTNERSHIP

PAUL MUSSLEMAN AND ELLEN B. BUCKNER

Background

In 2007, the University of Alabama at Birmingham's Lister Hill Library of the Health Sciences and the School of Nursing Departmental Honors Program created a partnership to integrate the use of library resources more effectively into the honors curriculum. Based on several years of introductory experiences, similar to orientations, on how to begin searches using databases, the new paradigm would enmesh these skills and the course requirements more deliberately. Although the skills pertained to work within a clinical discipline, the skills and knowledge acquired by the students could be applied to more general honors education environments. An honors curriculum should integrate resources at the highest level; access to and appreciation for the intellectual dialog available through published works are a critical part of the honors students' education. In science, development of evidence and critical appraisal of existing evidence require the ability to connect with the appropriate literature. Information literacy is the key to that kingdom.

Information Literacy

The Association of College and Research Libraries defines information literacy as the ability to "recognize, when information is needed and have the ability to locate, evaluate, and use effectively the needed information."[1] Information literacy develops over time with skills and practice, feedback, and integration. The role of the faculty member is assisting students in learning judgment within the context of the discipline. This includes recognizing when information is needed and evaluating the quality of the source. A critical step to information literacy, however, is accessing the literature that is focused on the particular topic and the level of evidence required.

Setting information literacy benchmarks for students throughout their education is an important practice, and students must have sufficient training in finding and evaluating resources to reach these benchmarks. Students should be taught to become increasingly proficient at recognizing and utilizing scholarly literature, and they will also need direction to make use of library databases and resources in a progressively sophisticated manner. Along with the ability to competently operate library databases and tools, students also must know about their area of study in order to discover and make use of the scholarly literature of their field. Under the tutelage of professors and library instructors, students learn to critically appraise and evaluate the literature of their field; library instruction, integrated into classroom instruction, provides students with a solid foundation for accessing and using that literature.

Often professors will invite librarians to introduce library resources and services. Typically these library orientation sessions occur during a student's freshman year, and librarians, having a brief period of time to spend with a class, provide, above all else, students with a general overview of library services and resources as well as a friendly face to attach to the library. For some students, these presentations are sufficient to adequately immerse them in all the library offers. For others, especially perhaps those lacking computer skills or those who believe Wikipedia or other non-scholarly sources are sufficient, the library and its resources appear unnecessary and but another hassle to avoid in the course of their studies. At many institutions students never receive library instruction beyond their freshman year, which makes reaching the information literacy milestones that faculty expect them to attain more difficult.

Progressive, dynamic, and multi-session library instruction, coupled with curricular instruction and assignments, increases the probability that students will effectively access and utilize library resources.[2] Library instruction should progress with and correspond to the information literacy benchmarks established by a school or department. For instance, if departments expect freshmen to find articles, librarians should then provide instruction on selecting and searching appropriate databases. If sophomores must access peer-reviewed literature, librarians should instruct those students on the search features and limits of the tools that are most appropriate. Similarly, the content of library instruction provided to juniors and seniors should address advanced topics: exploring varying levels of evidence in the literature; employing bibliographic management software, such as Endnote, Endnote Web, and Zotero; and critically evaluating resources.

A librarian's regular presence in the classroom ensures that a librarian is accessible to the students and that assistance is available at the time of need. The presence of librarians makes approaching them less threatening and increases the likelihood that students will use the library and seek their assistance in the future. One librarian working closely with students noted that the students he had worked with were "apt to use more sources, as well as more reliable and credible sources."[3] By explaining library tools and resources, librarians remove anxiety surrounding their use. A librarian's presence in the classroom can similarly remove unfavorable perceptions or anxieties students might have regarding librarians. Students often discover, once they utilize the services and expertise of librarians, that librarians are approachable and that their services are vast. Students quickly recognize the benefit to their school work and research. And it is not just the students who benefit from these relationships: librarians who are actively involved with their student-patron base can better determine what resources and services to cultivate and develop, what assignments and papers are coming up, and other information vital to having a useful library on campus.

Specific honors assignments that complement these skills involve taking the novice student into the literature in ways that match both their interests and the resources of the university. Early in their introduction to the literature, students may explore areas of interest or research articles authored by the faculty who mentor them. These initial access searches should culminate in assignments requiring summaries and critiques, such as the development of an annotated bibliography for a select number of articles. Annotated bibliographies have three components: the bibliographic citation, a summary of the article, and the student's critique of the article. These annotations are usually no longer than one single-spaced page. The annotated bibliography builds specific skills in the novice student pursuing honors work. It instills an appreciation for the accessibility, indexing, and reference capability of bibliographic data. In the summary the students practice paraphrasing and succinct summary of the content from the author's perspective. In science literature that often includes research, the student summaries require identifying the elements of scientific process: problem statement, hypothesis, methods, sample, instrumentation, findings, and conclusions. After following this brief and repetitive format for these summaries, students realize quickly that the formats vary across academe from discipline to discipline. The student choosing an interdisciplinary approach can recognize convergent and divergent processes in the literature of different disciplines. Students can explore with faculty or mentors the process of adapting and reconciling divergent philosophies. Finally, in the critique students must interpret the reading in ways that apply to their own projects. They must define the directions they will be pursuing and connect the literature to that journey. Even this task, as simple as a short paragraph critique, demands an affective connection with the students as they struggle with what they want to prove in the cognitive development of this area of interest and investigation. When students annotate the bibliography of a mentor's collected works, for example, the project is invaluable in introducing students into the professional development of a scientist or scholar in the field. They may use an author search to identify articles by their potential mentor and immediately connect with that person's early and current scholarship. They will recognize journals in their field and differentiate the level of scholarship and writing associated with each. They can see how faculty members' current research grew from building blocks present in earlier publications and developed to higher levels during the course of their career. They have an immediate connection with the language and principles through which the faculty member's current activities are communicated. This familiarity prepares them to discuss possible honors work realistically, integrated with the resources the faculty member is able and willing to provide. A set of three to five annotated bibliographies will certainly be sufficient to acquaint the students with the literature in ways that develop critical-thinking skills.

Information Literacy Skills

Students must acquire numerous skills in order to be information literate. Students must learn to differentiate between scholarly and non-scholarly sources. Scholarly works are typically defined as being peer reviewed and published in sources with extensive criteria for publication. Peer-reviewed sources use a pool of scholars with expertise in the appropriate academic area to review the manuscript. They are deemed peers because they are professionals in the field who have credentials equal to or higher than those of the author. They may also have received special training on the review process. Peer review includes discussion of the significance, theoretical basis, methods, results, relevance, implications, and ethical considerations. Peer reviewers[4] typically identify the connections with existing literature and whether the research paper follows a sound structural methodology and accurately references sources.[5] Sources with open editing, such as Wikipedia, may be helpful to students, but they do not provide that professional level of review for accuracy and quality although they can be helpful in locating other peer-reviewed sources. General searching on the Internet will likewise locate a wide diversity of sources, some being of high quality and value and many being unreliable and erroneous. If a website is affiliated with an organization replete with dedicated experts, such as the American Heart Association (AHA), then its panel-authored position papers are the opinions of experts and therefore a strong source for use in a research paper. An anonymous blog, however, cannot be treated as containing reliable information. Students should be cautioned on two points: one is that online sources representing the individual perspectives of an author may indeed be beneficial for certain purposes and therefore a support site for cancer survivors may well provide tips and strategies that represent first-person evaluations. From the perspective of survivors, this information and these narratives are significant. The second caution is that unusual or creative work may not always be recognized early in its development. In numerous instances, people ahead of their time were ridiculed or thrown out of professions because their observations contradicted the accepted canon. Without a doubt, appropriate referencing of sources and the development of independent critical judgment of a work demand engagement and understanding by the reader to fully comprehend its worth.

Of course, students must select and use the appropriate databases and resources to locate the relevant literature from their disciplines. Before learning the particulars of any one database, students must know how to design an effective search strategy. The first step is identifying key concepts in their research statements or questions. Then they must learn how to narrow key concepts into keyword components to build a search string. Students also exercise advanced skills by using the tools needed for effective search-string construction, such as the use of Boolean Operators (and, or, not), and the truncation of search words.

Once students understand how to build an effective search string, they are ready for instruction about selecting and using relevant databases. Librarian instruction and assistance regarding database selection can insure that time is not wasted searching databases that lack the information being sought. Guiding students to topically relevant databases can be accomplished through library presentations, especially when librarians arrange database collections into groupings by subject so that discovery of relevant databases becomes an intuitive process.

The next step, of course, is teaching students how to use the databases. Instruction on any database or resource should begin with a basic overview of that product. Basic features should at least include:

- How to access it.
- Its purpose.
- The types of publications included.
- Available formats of information (PDFs, images, video, etc.).
- Span of publication years included.
- If it contains full-text, some full-text, or no full-text.
- How to connect to full-text (if available).

The next phase is for librarians to teach students to use advanced database features. Advanced features should include:

- Conducting keyword searches.
- Using Boolean and special operators.
- Setting limits and applying expanders.
- Using history to revise and combine searches.
- Building searches using subject headings.
- Managing search results.

Over time, students will realize that many of the same functions are available across a number of databases. As they gain familiarity with one or two databases, their increased comfort and confidence will help them to effectively utilize other databases.

Although effectively using databases is important, database literacy does not equal information literacy; of course, without a certain fluency in the use of library databases and other library resources, students will not be able to meet the information literacy standards expected of them by their instructors, colleagues, and other professionals.[6]

Because novices often conduct searches in a trial-and-error process, faculty guidance about where the keywords and operators will lead them can be immeasurably important. In many databases, for example, input of a keyword can give students a list of subject headings that are well-designed classifications of knowledge. Instructors should explain the difference that using a simple keyword or a subject heading can make in regards to search precision. The cognitive concept of general to specific, or broad to focused, is an important operative search concept as students refine their searches to obtain relevant articles on a cohesive topic. The ability to pursue or disregard articles is a technique that involves decision-making skills. For example, a student search may identify 100 articles on a focused topic. In the process of reviewing these, the student may see that an unrelated concept with the same keyword appears in the list. The initial reading of the list of articles can help the student decide which articles may prove helpful and which should be purged from the list. In these initial searches, the goal is learning to tailor a search that progresses from a general to an increasingly specific topic. The decision making involved in reviewing the list of articles is more demanding than merely looking at how many articles a particular search retrieved. The process of introducing information literacy instruction over time means the students gain experience in searching and other skills in manageable doses. A conceptual approach defining the sphere of interest with progressively more clarity has more meaning for the student than constructing the perfect mechanism for the search engine. Assimilation of the content of the articles using titles and abstracts to construct the search constitutes the honors component to the work.

Developing these skills in honors students is one of the quickest and easiest ways to infuse the knowledge into the whole class or major cohort. An additional benefit is that once assertive honors students find educational meaning in these literature-acquisition processes, they rapidly pass the information on to non-honors peers. Some students at UAB have conducted teaching sessions with friends and even groups of peers who were struggling to find sources for a course paper. In this information and technological age, the ripple effect accelerates and travels digitally. Because all students in the university have access to these resources, placing the information literacy skills in the hands of students with leadership ability is an effective way to engage the student body as a whole.

International Perspectives and Freely Available and Discounted Resources

Students throughout the world soon recognize that these processes are international in scope. Certainly faculty involved in international collaborations are aware of the extent to which obtaining knowledge electronically is critical to scholarship worldwide. An honors study abroad course may provide a mechanism for students to draw on the literature of the destination country. Questions developed in one culture may be shared with and considered by students from another. Student-to-student exchange can recognize the contributions of each to scholarship.

Students also recognize that major research databases facilitate access to the literature worldwide and opportunities for potential collaboration across geographic distances. Databases such as PubMed, Social Science Citation Index (SSCI), Cumulative Index to Nursing and Allied Health Literature (CINAHL), Educational Resources Information Center (ERIC), and the Cochrane Library are complemented by Scientific Electronic Library Online (SciELO), Latin American and Caribbean Health Sciences (LILACS), Health InterNetwork Access to Research Initiative (HINARI), and others that open connections between continents, peoples, and cultures.

While in many cases the shift from print to electronic form has generated greater access to publications, students pursuing advanced research will likely realize that in some situations it has created new barriers. Major institutions, libraries, and library cooperatives purchase access to large online collections, enabling their patrons to access scholarly literature. At the same time, many locations in the United States and around the world lack the computer hardware, Internet access, and funding for accessing licensed resources. Fortunately, a number of resources provide scholars with free or discounted access to scholarly literature. Selected databases available to students in the United States and to international scholars worldwide are listed and described in Appendices A and B. These examples represent the ways that the international academic community has increased access to literature. During their interactions with the librarians, students also learn about projects in the health sciences that enable people to access a wealth of online and electronic health science resources.

In 2001, the WiderNet Project, a service program based at the University of Iowa's School of Library and Information Science, launched the e-Granary Digital Library. The e-Granary Digital Library, also known as the Internet-in-a-box, is a digital storage device that is loaded with content from numerous websites and other content providers and then sold for use in areas with limited or no Internet connectivity. The device can be run on one computer or on a server with a network of computers. There are approximately ten million documents, including books, journals, entire websites, and educational and computer software, in each e-Granary device, all of them searchable using a powerful, built-in search engine. The low cost of the service makes it an excellent way for developing countries to gain access to a vast health library.[7] In 2008, the director of the National Institutes of Health (NIH) mandated that any peer-reviewed journal article resulting from NIH-funded research must be deposited into the free, publicly accessible database PubMed Central <http://www.pubmedcentral.nih.gov/>. These articles must be deposited in the database no later than twelve months after they are published to provide researchers worldwide with a number of free and relatively new works. In addition to works resulting from NIH research, PubMed Central also contains many biomedical articles that have been submitted voluntarily by journal publishers whose journals meet PubMed Central's editorial standards. As part of its mission, PubMed Central agreed to provide access to articles in the database in perpetuity.[8]

Conclusion

Information literacy is an essential quality for serious students. Librarians contribute to information literacy through building and maintaining the best possible collections, providing library instruction, and assisting in literature searches. Instructors provide students with subject expertise and related skills, thus enabling students to critically appraise and digest the information they have discovered in their searches. Ideally, both librarians and instructors will work in conjunction with one another, using and sharing their own unique and valuable skill sets with the students and each other. Honors students are particularly suited to developing skills of information literacy because of their academic sophistication, their thirst for knowledge, and their assertiveness. Their skill development will infuse the academic institution as a whole with intellectual curiosity and ways to locate resources and knowledge. Honors curricula should support information literacy through specific partnerships and collaborations with librarians. This intentional educational process can build skills that are precursors for scholarship and lifetime learning.

Assignments and Questions for Discussion

1. Locate three journal articles on the selected topic and write an annotated bibliography for each. An annotated bibliography consists of the bibliographic citation, a short summary of the article, and a critique of the article. The annotated bibliography should be one single-spaced page and meet the formatting requirements (APA, Chicago, or other style) of the disciplines. The summary should be your summary and not the author's abstract. The critique should relate the article to your honors work and project/paper idea or development.

2. Discuss the development from student to professor of a scholar. What are the stages evident in that scholar's published works? Include information from your interview of this scholar as a potential mentor and a description of current work in progress.
3. How does information literacy support the development of humankind worldwide? Are we in the US ahead or behind others internationally?

Bibliography

Association of College and Research Libraries. "Information Literacy Competency Standards for Higher Education." Accessed September 3, 2012. <http://www.ala.org/acrl/standards/informationliteracycompetency>.

Burns, Helen K., and Susan M. Foley. "Building a Foundation for an Evidence-Based Approach to Practice: Teaching Basic Concepts to Undergraduate Freshman Students." *Journal of Professional Nursing* 21, no. 6 (November/December, 2005): 6.

California Polytechnic State University. "Finding Peer-reviewed or Refereed Journals." Accessed September 3, 2012. <http://lib.calpoly.edu/research/guides/peer.html>.

Hall, Russell A. "The "Embedded" Librarian in a Freshman Speech Class: Information Literacy Instruction in Action." *College & Research Libraries News* 69, no. 1 (January 2008): 28–30.

Harrod, Tom. "Institute for Biomedical Sciences: Himmelfarb Library Guide: Scholarly Communication and Peer Review." last modified July 3, 2012. <http://libguides.gwumc.edu/content.php?pid=53748&sid=1122300>.

National Institutes of Health. "Frequently Asked Questions about the NIH Public Access Policy." Accessed September 3, 2012. <http://publicaccess.nih.gov/FAQ.htm>.

WiderNet Project. "eGranary Digital Library." Accessed September 3, 2012. <http://www.widernet.org/egranary/>.

Notes

[1]Association of College and Research Libraries, "Information Literacy Competency Standards for Higher Education," accessed September 3, 2012. <http://www.ala.org/acrl/standards/informationliteracycompetency>.

[2]Helen K. Burns and Susan M. Foley, "Building a Foundation for an Evidence-Based Approach to Practice: Teaching Basic Concepts to Undergraduate Freshman Students," *Journal of Professional Nursing* 21, no. 6 (November/December, 2005): 6.

[3]Russell A. Hall, "The "Embedded" Librarian in a Freshman Speech Class: Information Literacy Instruction in Action," *College & Research Libraries News* 69, no. 1 (January 2008): 28–30.

[4]California Polytechnic State University, "Finding Peer-reviewed or Refereed Journals," accessed September 3, 2012. <http://lib.calpoly.edu/research/guides/peer.html>.

[5]Tom Harrod, "Institute for Biomedical Sciences: Himmelfarb Library Guide: Scholarly Communication and Peer Review," last modified July 3, 2012. <http://libguides.gwumc.edu/content.php?pid=53748&sid=1122300>.

[6]Association of College and Research Libraries, "Information Literacy Competency Standards for Higher Education," accessed September 3, 2012, <http://www.ala.org/acrl/standards/information literacycompetency>.

[7]WiderNet Project, "eGranary Digital Library," accessed September 3, 2012, <http://www.widernet.org/egranary/>.

[8]National Institutes of Health, "Frequently Asked Questions about the NIH Public Access Policy," accessed September 3, 2012. <http://publicaccess.nih.gov/FAQ.htm>.

APPENDIX A:

Some Commonly Used Academic Databases

Academic Search Premier is comprised of citations and abstracts from over 8,200 journals, with full text for more than 4,500 of those titles. The database contains articles from business, education, biology, chemistry, engineering, physics, psychology, and theology publications. Contains citations from as far back as 1975. <http://www.ebscohost.com/academic/academic-search-premier>.

CINAHL (Cumulative Index to Nursing & Allied Health Literature) provides access to citations from over 2,938 journals from the fields of nursing and allied health. Within the database are over 1,000,000 entries dating back as far as 1981. More comprehensive versions of CINAHL are available, which provide an even greater range of publication dates covered. <http://www.ebscohost.com/thisTopic.php?marketID=6&topicID=53>.

Cochrane Library is comprised of evidential literature to be used in healthcare decision making. The database contains systematic reviews of evidence from Cochrane as well as systematic reviews from other sources. The Cochrane database has a reputation for being one of the most-respected evidence-based-practice databases. <http://www.thecochranelibrary.com/>.

ERIC (Educational Resource Information Center) provides access to education literature and resources. The database contains more than 1,194,000 bibliographic records and includes links to more than 100,000 full-text documents. ERIC is sponsored by the U.S. Department of Education, Institute of Education Sciences (IES). <http://www.eric.ed.gov/>.

PsycINFO provides abstracts and citations for scholarly works from over 2000 journals in the behavioral sciences and mental health fields. The database has over 2.2 million citations from mostly peer-reviewed journals from the 1800's to present. PsycINFO is a product of the American Psychological Association (APA). <http://www.apa.org/pubs/databases/psycinfo/index.aspx>.

PubMed is a free database providing access to millions of bibliographic citations and abstracts in the fields of medicine, nursing, dentistry, veterinary medicine, the health care system, and preclinical sciences. It was developed and is maintained by the National Center for

Biotechnology Information (NCBI) at the U.S. National Library of Medicine (NLM). <http://www.pubmed.gov>.

SSCI (Social Sciences Citation Index) contains citations from over 1,700 of the world's most prominent scholarly social sciences journals from over fifty disciplines. They also cover individually selected, relevant items from approximately 3,300 of the world's leading science and technology journals. <http://scientific.thomsonreuters.com/products/ssci/>.

Web of Science is a database containing citations from over 9,200 journals in 45 different languages. The database includes citations from the science, social science, and arts and humanities publications. Web of Science is often utilized to discover who is citing whom in scholarly works. <http://scientific.thomson.com/products/wos/>.

APPENDIX B:

Selected Latin American and International Databases

LILACS (Latin American & Caribbean Health Sciences Literature) covers literature related to the health sciences that has been published in Latin American countries and the Caribbean since 1982. It is published by WHO Regional Offices. It contains articles from about 670 of the most well-known journals in the medicine field, plus other documents such as theses, books, conference proceedings, scientific reports, and governmental publications. LILACS is a cooperative product of the Latin American and Caribbean Centre on Health Sciences Information, coordinated by **BIREME (Biblioteca Regional de Medicina)**. <http://www.bireme.br>.

eGranary Digital Library provides access to online and electronic documents to portions of the world where there is no or ineffective internet access. eGranary bills itself as "the Internet in a box"; it is comprised of a 750gb hard drive that contains millions of pages of information pulled from many prominent websites whose owners have given permission for their content to be used in this project. Those purchasing an eGranary drive can connect it to a server on a local computer network or connect it to a single computer. <http://www.egranary.org/>.

HINARI (Health InterNetwork Access to Research Initiative) is a product of the World Health Organization. HINARI provides developing countries online access to the world's biomedical and related subject areas journals at little or no cost. <http://www.who.int/hinari/en/>.

SciELO (Scientific Electronic Library Online) is a virtual library for Latin-America, the Caribbean, Spain, and Portugal. The following link provides some info on SciELO's model <http://www.scielo.org/php/level.php?lang=en&component=42&item=1>.

SECTION II:
SCIENCE AND SOCIETY

Chapter 4

SENCER: HONORS SCIENCE FOR ALL HONORS STUDENTS

Mariah Birgen

Introduction

The Science Education for New Civic Engagement and Responsibilities (SENCER) project, which has its roots in a CDC-sponsored initiative that focused higher education's attention on HIV, robustly connects science and civic engagement by teaching current, contested, and unresolved public issues in basic science courses. SENCER features thirty-nine field-tested courses, programs, and learning communities as well as the SENCER Models that take rigorous interdisciplinary approaches to teaching basic science and strengthening students' capacities to become engaged citizens. The models embody aspects of the SENCER Ideals and focus on some of the most complex and vexing issues of the time. These ideals and models, although originally designed to help students overcome both unfounded fears and unquestioning awe of science, could be used as a way of developing honors science courses and programs. By focusing on contested issues, the SENCER project encourages student engagement with troublesome problems requiring solutions from a multitude of disciplines, so-called "multidisciplinary trouble," and with civic questions that require immediate attention. SENCER shows the power of science by identifying the dimensions of a public issue that can be better understood through certain mathematical and scientific ways of knowing while also revealing the limits of science by identifying the elements of public issues where science does not help people decide what to do. The SENCER Ideals include conceiving of the intellectual project as practical and engaged from the start as opposed to other science education models that view the mind as a storage shed where abstract knowledge may be secreted for vague potential uses and locating the responsibility as well as the burdens and the pleasures of discovery as the work of the student.

History and Overview of SENCER

Sponsored by the American Association of Colleges and Universities, SENCER received the first of a series of Course, Curriculum, and Laboratory Improvement (CCLI) grants from the National Science Foundation (NSF) to create a nationwide project in the fall of 1999. SENCER is now the signature program of the National Center for Science and Civic Engagement, which was established in affiliation with Harrisburg University of Science and Technology (National Center for Science and Civic Engagement 2012). The original description of the SENCER project connected science education with civic engagement by teaching science through the study of complex public issues. SENCER models teach biology through the study of HIV disease or the Human Genome Project; physics is taught through the study of the challenges of nuclear disarmament or hypotheses about the origins of the universe; chemistry is taught through the study of air pollution, water quality, or crime; and mathematics is taught by examining the reliability of statistics or studying risk/benefit analysis. The ultimate outcome for students is connected learning.

SENCER promotes large-scale reform in undergraduate science, technology, engineering, and mathematics (STEM) education through intensive professional development for faculty, a strong focus on local systemic change, and the use of improved assessment practices. SENCER faculty use an assessment instrument developed with partial support from several NSF initiatives to improve undergraduate education. This instrument is known as the Student Assessment of Learning Gains (SALG) and is freely available for public use at <http://www.salgsite.org> (Seymour, Carroll, and Weston 2007).

SENCER Institutes are the core activity of the project. These are team-based residential institutes for faculty, administrators, and advanced graduate students who are planning to initiate SENCER approaches. Additionally, the SENCER Virtual Community links innovators together and supports the dissemination of resources to encourage reform. Finally, the sencer.net website is a source of materials collected over the last twelve years. The materials are all available for use to improve the teaching of science.

The first SENCER Summer Institute was held in August 2001 at Santa Clara University. The following year, international scientists joined the institute. Soon after, a strong emphasis on pre-service science education developed; however, the core of the SENCER mission stayed strong: teaching science skills and science concepts by engaging students with civic issues. Through the years, several universities have sent honors teams to the SENCER Summer Institute specifically to develop honors science courses. Some of these have become Model courses and can be found on the website.

SENCER Ideals

The SENCER Ideals form the core of the entire SENCER project. Although they are not a set of goals and student outcomes, they are assessable statements. These ideals include a set of concepts around which a new or renewing honors science curriculum can be built. Because SENCER originally focused on science courses for non-science students, these ideals work for *all* honors students, not just those majoring in Pre-Med. The Ideals also subtly address the views of science faculty that all courses are honors courses and that honors courses mean more work for students.

The SENCER project includes eight Ideals (National Center for Science and Civic Engagement 2012):

- SENCER robustly connects science and civic engagement by teaching through complex, contested, capacious, current, and unresolved public issues to basic science.
- SENCER invites students to put scientific knowledge and scientific method to immediate use on matters of immediate interest to students.
- SENCER helps to reveal the limits of science by identifying the elements of public issues where science does not help people decide what to do.
- SENCER shows the power of science by identifying the dimensions of a public issue that can be better understood with certain mathematical and scientific ways of knowing.
- SENCER conceives of the intellectual project as practical and engaged from the start, as opposed to science education models that view the mind as a storage shed where abstract knowledge may be secreted for vague potential uses.
- SENCER extracts from the immediate issues the larger, common lessons about scientific processes and methods.
- SENCER locates the responsibility as well as the burdens and the pleasures of discovery as the work of the student.
- SENCER, by focusing on contested issues, encourages student engagement with “multidisciplinary trouble” and with civic questions

that require attention now. By doing so, SENCER helps students overcome both unfounded fears and unquestioning awe of science.

The foundations of these ideals appeal to students who join honors programs because they place the responsibility of learning on the shoulders of the students. These students desire an engagement with the intellectual project and quickly see that they will need to become multidisciplinary problem solvers (National Collegiate Honors Council 2012).

SENCER Models

As of spring 2012, forty-four SENCER Models existed. Most of these are single-semester courses that have been offered repeatedly at colleges and universities around the country. A few of them are two-semester sequences, and some of the most recent are "emerging models" that have been developed as a result of the faculty involvement in SENCER although they have not yet been fully field-tested. Courses that have been specifically created for honors program are listed below with the associated college or university:

- Science and the Connecticut Coast (Southern Connecticut State University)
- Addiction: Biology, Psychology, and Society (Indiana University-Purdue University Fort Wayne)
- Chance (Spelman College)
- Life Science in Context: Sub-Saharan Africa and HIV/AIDS (North Carolina Wesleyan College and Meredith College)
- The Power of Water (Longwood University)

By going to SENCER.net, one can download full .pdf documents for each of the model courses. Each model includes information that explains why the model works with SENCER, a description of the course or courses, and a description of the individuals who created the course. Also included is a description of the college or university where the course is offered, the role of the course in the larger institution, and various assessment strategies. Contact information is available, and the instructors are often interested in helping other faculty adapt their model for future use. These models form an excellent framework for an honors director. With few adjustments, many of these courses can be used within one's own curriculum to provide an honors science course for non-science majors.

SENCER Institutes

Held every summer since August 2001, SENCER Summer Institutes offer teams of faculty the chance to come together to work on science courses that use civic engagement and responsibility to teach basic science. In the beginning, teams included non-science faculty, science faculty, and education faculty and were required to include an administrative member. Now that SENCER is more nationally established, the teams are still encouraged to be interdisciplinary, but they are no longer given any strict requirements. Teams are placed in homerooms with other teams from similar backgrounds and are given a homeroom instructor who is on the SENCER faculty. The main responsibility of each team is either to create or to modify a course to fit with the SENCER ideals.

To help with this task, teams received a course-development template that walks team members through a goal-centered course-creation process. Faculty are asked questions about the course goals and student goals; what research questions may be raised by the course; and what anticipated changes in the student, the department, and the community would be expected as a result of the course. Teams are also asked about the structure and pedagogy of the course, what the student-learning objectives are, and what learning assessments would accompany the course to match the student-learning objectives. Teams have several hours, spread out over the course of the institute, to complete this course-development template.

Other parts of the institute include plenary sessions with respected experts in the field of science education, concurrent sessions to help faculty and administrators make the case for changing science education, concurrent sessions on new pedagogies in teaching science, and pre- and post-institute workshops including a very popular post-institute workshop on NSF grant writing. Each year, alumni from the previous institute attend, providing support and advice for the hardworking teams. Also, members from teams planning to attend the following year's institute often preview the program for their institution.

Overall, the SENCER summer institutes are hardworking, fast-paced, and intensive three- or four-day opportunities for both course and faculty development. The summer institutes are an excellent way of revitalizing tired and overworked faculty and are often the best way to revamp honors science courses and curricula. On the other hand, if the Science faculty are too overworked to attend an institute, representatives from SENCER will do site visits. House calls are campus visits by SENCER leadership fellows, alumni, and national program staff. These peer consultation visits are tailored to specific needs and challenges ranging from basic orientation to the SENCER approach to help with course design, implementation, assessment, and expansion.

Conclusion

Over the years, several SENCER Institute teams have specifically focused on honors courses and programs. The University of Southern Maine has an honors sequence called the Body Strand, which includes "Religious and Scientific Perspectives on Human Origins and the Human Body" and "Interdisciplinary Inquiry in the Sciences of the Human Body." Alma College offers two honors seminars that link public policy to environmental sciences. Through SENCER, Chapman University developed a required science course for all non-science honors students, and Augsburg College developed an interdisciplinary course for sophomore and junior non-science honors students.

In addition to SENCER model courses and the SENCER Summer Institute, SENCER provides background papers encouraging faculty to teach sensitive subjects like stem cell research or AIDS in Africa. The SENCER house call program can provide consultation on campus to further one's reform efforts and can even recommend appropriate outside consultants if necessary. The SENCER community itself can be a resource for honors science instructors as they strive to create a valuable science experience that interests, challenges, and educates honors students in their scientific specialties.

Bibliography

National Center for Science and Civic Engagement. *SENCER*. 2012. <http://www.ncsce.net/Initiatives/SENCER.cfm> (accessed 2012 28-August).

—. *SENCER Ideals*. 2012. <http://www.sencer.net/About/sencerideals.cfm> (accessed 2012 28-August).

National Collegiate Honors Council. *Honors Philosophy*. 2012. <http://nchchonors.org/faculty-directors/honors-philosophy-or-is-it-philosophies/> (accessed 2012 28-August).

Seymour, Elaine, Stephen Carroll, and Tim Weston. *SALG – Student Assessment of Their Learning Gains*. 2007. <http://www.salgsite.org> (accessed 2012 28-August).

Chapter 5

PHILOSOPHY IN THE SERVICE OF SCIENCE: HOW NON-SCIENCE HONORS COURSES CAN USE THE EVOLUTION-ID CONTROVERSY TO IMPROVE SCIENTIFIC LITERACY

THI LAM

Explanation of the Method

Why does a significant proportion of the American public reject evolutionary science in favor of intelligent design (ID)? A 2005 national opinion poll, for example, revealed that only 40% of U.S. adults accept evolution as a scientifically sound theory. The rest of the 60% surveyed were either unsure of or outright rejected evolution.[1] The politically charged controversy surrounding evolution and ID, which pits a view of humanity as a complex product of nature against a view of humanity as the creation of an intelligent designer, is an excellent topic of study for honors students. The topic usually has a high level of student interest because of the media coverage of this controversy and the religious implications.[2] Students can explore the controversy from a myriad of perspectives in an honors curriculum: philosophically, scientifically, legally, religiously, sociologically, and politically. Pedagogically then, the topic is conducive to an interdisciplinary approach. Non-science courses can significantly improve students' understanding of evolutionary theory, and science in general, by exploring the non-scientific impediments that students often have against evolution.

Among the general public, including students, impediments to the acceptance of evolution are usually non-scientific in nature; mostly they are philosophical or religious.[3] Honors courses, especially those in the humanities, can help students explore these non-scientific objections in greater depth. Evolutionary theory is not without its critics, of course, and should be aggressively studied as much as Intelligent Design. For the instructor, such courses can provide opportunities to clarify the scientific and philosophical misunderstandings of evolution and ID.[4] The topic can serve as a stand-alone course or as a major component of a broader course. How the material is structured is left to the discretion of the instructor based on factors such as student demographics, pedagogical objectives, and type of course.

A particularly effective pedagogical strategy is to have students compare and contrast the philosophical and scientific underpinnings of the two theories. Such side-by-side comparisons allow students to examine the arguments for and criticisms of each theory. This strategy can alleviate the following impediments to scientific proficiency among students: scientific illiteracy, ignorance of current research and findings, and skepticism or incredulity about scientific findings.[5] Furthermore, students can discuss the philosophical and religious ramifications of accepting evolutionary theory, especially whether such acceptance necessarily entails a rejection of their religious beliefs.[6] The rest of this chapter will present one example of how this topic can be studied in an honors philosophy course.

Philosophy as an Illustration

Philosophy is the academic discipline that analyzes and critiques fundamental beliefs and concepts. In the author's introductory philosophy courses, the topic of evolution and ID are designated as a capstone project reserved for the end of the course. As such, every relevant philosophical concept, theory, and idea that students addressed throughout the course is brought to bear on this topic.

To this end, the author reviewed the materials in the course that could shed light on students' understanding of the evolution-ID controversy. In the epistemology chapter, for example, students learn the various theories of knowledge such as rationalism, empiricism, transcendental idealism, and skepticism. These theories account for how people acquire, justify, and evaluate knowledge beliefs. In the meaning of life chapter, students discuss the three broad theories that account for life's meaning: the religious, subjectivist, and nihilistic theories. In particular, students are encouraged to reflect upon whether accepting evolutionary theory is consistent with leading a meaningful life. That is, if evolution is accepted as true, what implications, if any, can be drawn about life's meaning? For the philosophy of science chapter, students explore the following questions: What is science (as opposed to religion, mythology, art)? What makes an explanation scientific (as opposed to religious)? How does science (as opposed to religion) substantiate its knowledge claims? Are there any limitations to science? This chapter provides an excellent opportunity to discuss the distinguishing hallmarks of science (e.g., evidence-based, testability, peer-review, fallibility).[7] Regardless of the branch of philosophy under discussion, then, each chapter contains a plethora of competing theories for students to compare and contrast.

By the time the students encounter the evolution-ID chapter, they are already familiar with comparing and contrasting two or more theories. They should feel comfortable setting two theories side by side and assessing their relative strengths and weaknesses. Students can better understand a theory if they see how it measures up to another. Figure 1 is a sample comparison chart for science and religion. It makes a useful pedagogical springboard for further class discussion, especially in clarifying the common misunderstandings that plague each theory.

Figure 1: Sample Comparison Chart for Science and Religion

Science	**Religion**
Human scientists make mistakes.	Deities cannot make mistakes.
Scientists have not explained every natural phenomenon.	Natural phenomena can be explained by reference to deities.
Scientific theories must be supported by adequate evidence before the scientific community accepts them.	One may exercise faith in deities and the written scriptures of a religion.
Scientific knowledge is provisionally accepted.	Divine revelation can be trusted with absolute certainty.
Scientific theories can change over time.	Divine revelation does not change.
Scientific theories can be overthrown.	Divine truths are timeless.

Maximizing Critical Thinking; Minimizing Rationalization

Due to the inherent nature of philosophy, critical thinking is the cornerstone of the discipline. Such thinking should be carefully distinguished from something that is often mistaken for it: rationalization. The problem with rationalization is that any person can commit it. Given sufficient time and ingenuity, a person can marshal evidence in support of virtually any position. This kind of thinking is not what is sought in philosophy, or in most academic courses, because it only reinforces rather than evaluates people's existing beliefs. Even when students adduce evidence in support of their position, they need to be wary of committing the confirmation bias, which says that people have the tendency to seek evidence that confirms already-held beliefs but ignore, reject, or explain away evidence that counters those beliefs.

When discussing an emotionally charged topic such as evolution and ID, there are several ways to minimize, though perhaps not completely eradicate, the intellectually deleterious effects of rationalization and the confirmation bias. Here are some suggestions for setting up the classroom:

- *Create a nonthreatening classroom environment that is conducive to critical discussion.* Students are willing to share their views when they feel comfortable with their classmates and the instructor. Students often take their cues from the instructor. If they feel that the instructor desires their input and respects their class contribution, then they will feel more comfortable disclosing their personal opinions.[8] No one student or select group of students should dominate the discussion. Everyone's participation should be equally encouraged.
- *Be as objective as possible.* This posture might be challenging for an instructor who feels very strongly towards one side of the controversy. Instructors should present both sides as fairly as possible. They should then encourage their students to evaluate the evidence (pros and cons) for themselves. Some instructors may even want to refrain from giving their personal views on the topic. This tactic may be necessary if the instructor feels that such personal disclosures would bias classroom discussions.
- *Refrain from passing judgment on students' opinions.* Students will not open up to the instructor if they feel that their beliefs will be publicly ridiculed. They do not want to appear unintelligent in the presence of their classmates. This suggestion does not imply that the instructor has to agree with the student's comments. Even if instructors

completely disagree with a comment, they should not publicly embarrass the student, but should rather use that opportunity to explore the comment in a nonconfrontational, albeit Socratic, manner. If instructors fail to follow this rule, then that occasion will most likely be the last time that they will hear from the student.

- *Incorporate humor to lighten the mood.* The topic of evolution and ID is a weighty subject in any course. Tactful humor can help to lighten the gravity of the topic and contribute to the creation of a nonthreatening classroom environment. Students who find the classroom enjoyable will more likely attend class, contribute to class discussions, and score high marks on exams than their counterparts who lack this enjoyment.

These classroom preparations could be even more effective if the students were intellectually prepared to absorb the course content. To this end, instructors should encourage the students to do the following:

- *Have an open but critical mind.* Critical thinking is a mean between two extremes: closed-mindedness and gullibility. On the one extreme, people are so closed-minded that new information no longer gets through to them. When this scenario occurs, the learning process shuts down. On the other extreme, people will believe anything that they read or hear. When that happens, the person becomes gullible. Students should avoid those two pitfalls; they should think, but think critically.
- *Examine an argument's presuppositions, one's own as well as others.* Students come into the classroom with a wide range of beliefs and opinions. Most of these beliefs have probably not been subjected to critical, systematic scrutiny. What better place to do this than an honors class? The goal of the inquiry is not to necessarily destroy those beliefs, but, rather, to explore the strength of the arguments that support those beliefs. How strongly they should hold onto a belief should correspond to its evidential support.
- *Characterize your opponent's position fairly.* For the sake of intellectual fairness, do not commit the straw man fallacy. That is to say, when presenting an opponent's argument, do so in a nonbiased way, giving that person the benefit of the doubt. Students should summarize their opponent's arguments in a way that does justice to the full force of the arguments. They must avoid simplistic generalizations or caricaturized summaries of the opposing viewpoint. Students will better appreciate the significance of this advice if they were to ever become the target of such unfair attacks.

- *Do not get defensive.* In an academic setting, especially in an honors course, there should be no reason for students to become defensive. All the participants can learn from each other; they should respect other viewpoints, even those they reject. When students feel emotionally overwhelmed at any point in the discussion, encourage them to take a moment to collect their thoughts and then articulate the reasons for their disagreement.
- *Do not let one's ego impede the critical-thinking process.* The point of a class discussion or presentation is to encourage the participants to reflect critically on the material. The goal is not to win an argument or one-up a classmate. As a sign of intellectual humility, students should be prepared to modify their beliefs if they do not stand up to critical scrutiny. When beliefs become sacrosanct, critical thinking will be stifled and intellectual development will be hindered.

Conclusion

The author uses the evolution-ID controversy in philosophy courses to introduce students to the wonders of science and philosophy. For students to benefit from such classes, however, honors instructors need to carefully structure the course in a manner that is conducive to maximizing learning and minimizing rationalization. The evolution-ID controversy is a provocative issue that captures students' attention and forces them to explore the similarities and differences between science and religion.[9] In the process, they should better understand the fundamental nature of science, its differentiation from various non-scientific ways of understanding, and the importance of scientific knowledge to their future personal and professional lives. A well-structured honors course has the ability to accomplish all of these things.[10]

Bibliography

Alters, Brian, and Sandra Alters. *Defending Evolution: A Guide to the Creation/Evolution Controversy.* Sudbury, MA: Jones and Bartlett Press, 2001.

Bisho, Beth. A., and Charles W. Anderso. "Student Conceptions of Natural Selection and its Role in Evolution." *Journal of Research in Science Teaching* 27 (1990): 415–427.

Brumby, Margaret N. "Misconceptions about the Concept of Natural Selection by Medical Biology Students." *Science Education* 68 (1984): 493–503.

Collin, Francis. *The Language of God: A Scientist Presents Evidence for Belief.* New York: Free Press, 2007.

Dennett, Daniel. *Darwin's Dangerous Idea: Evolution and the Meanings of Life.* New York: Touchstone, 1995.

Hawking, Stephen, Kip Thorne, Igor Novikov, Timothy Ferris, and Alan Lightman. *The Future of Spacetime.* New York: W.W. Norton Press, 2002.

Kitcher, Philip. *Living with Darwin: Evolution, Design, and the Future of Faith.* New York: Oxford, 2007.

Miller, John, Eugenie Scott, and Shinji Okamoto. "Public Acceptance of Evolution." *Science* 313 (August 2006): 765–766.

Miller, Kenneth Miller. *Finding Darwin's God: A Scientist's Search for Common Ground Between God and Evolution.* New York: Harper Press, 2007.

Sadker, Myra and David Sadke. *Teachers, Schools, and Society.* New York: McGraw-Hill, 2003.

Shermer, Michael. *The Borderlands of Science: Where Sense Meets Nonsense.* New York: Oxford University Press, 2001.

Notes

[1]See John Miller, Eugenie Scott, and Shinji Okamoto, "Public Acceptance of Evolution," *Science* 313 (August 2006): 765–766.

[2]For an insightful program on students' struggle to reconcile their faith with evolution at a conservative Evangelical Christian college, see PBS's *Evolution* (2001).

[3]See Brian Alters and Sandra Alters, *Defending Evolution: A Guide to the Creation/Evolution Controversy* (Sudbury, MA: Jones and Bartlett, 2001), chapters 3 and 4.

[4]See Beth. A. Bishop, and Charles W. Anderson, "Student Conceptions of Natural Selection and its Role in Evolution," *Journal of Research in Science Teaching* 27 (1990): 415–427 and Margaret N. Brumby, "Misconceptions About the Concept of Natural Selection by Medical Biology Students," *Science Education* 68 (1984): 493–503.

[5]See Stephen Hawking, Kip Thorne, Igor Novikov, Timothy Ferris, and Alan Lightman, *The Future of Spacetime* (New York: W.W. Norton, 2002): 153–170.

[6]For examples of professional scientists who are able to reconcile their acceptance of evolutionary science with their religious commitments, see Francis Collins's *The Language of God: A Scientist Presents Evidence for Belief* (New York: Free Press, 2007) and Kenneth Miller's *Finding Darwin's God: A Scientist's Search for Common Ground Between God and Evolution* (New York: Harper, 2007).

[7]For an illuminating discussion of the nature of legitimate science and the distinguishing hallmarks of pseudoscience, see Michael Shermer's *The Borderlands of Science: Where Sense Meets Nonsense* (New York: Oxford, 2001).

[8]Myra Sadker and David Sadker, *Teachers, Schools, and Society* (New York: McGraw-Hill, 2003): 102.

[9]For book-length discussions of how evolution has profoundly affected our understanding of ourselves, our place in the universe, and our religious beliefs and aspiration, see Philip Kitcher's *Living with Darwin: Evolution, Design, and the Future of Faith* (New York: Oxford, 2007) and Daniel Dennett's *Darwin's Dangerous Idea: Evolution and the Meanings of Life* (New York: Touchstone, 1995).

[10]For more pedagogical suggestions, see Alters, *Defending Evolution,* chapter 10.

APPENDIX A:

Group Discussion Questions

1. Does your church, synagogue, or temple have an official position on evolution? If so, do you agree with it? Why or why not?
2. Do you see any necessary conflict between evolutionary science and religious commitment? Can a person of faith consistently accept evolution and still maintain his or her faith?
3. What do the various religions say about the origin, development, and diversity of life? Are any religious accounts compatible with the evolutionary account?
4. Read the following court cases involving the teaching of Intelligent Design and summarize the court's position in each one: Scopes v. State (1927), Epperson v. Arkansas (1968), Seagraves v. State of California (1981), McLean v. Arkansas Board of Education (1982), Edwards v. Aguillard (1987), Freiler v. Tangipahoa Parrish Board of Education (1999), Selman v. Cobb County School District (2005), and Kitzmiller v. Dover Area School District (2005).
5. Interpret and evaluate the following quotation by Charles Darwin: "There is grandeur in this view of life, with its several powers, having been originally breathed by the Creator into a few forms or into one, and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being evolved."

APPENDIX B:

Web Resources Supportive of Evolution Education

- American Association for the Advancement of Science <http://www.aaas.org>.

  An international non-profit organization dedicated to advancing science around the world by serving as an educator, leader, spokesperson and professional association. In particular, the AAAS's *Dialogue on Science, Ethics, and Religion* facilitates communication between scientific and religious communities.

- Becoming Human <http://www.becominghuman.org>.

  Contains interactive multimedia, research, and scholarship to promote greater understanding of the course of human evolution.

- The National Academies <http://www.nas.edu>.

  Brings together committees of experts in all areas of scientific and technological endeavor. These experts serve *pro bono* to address critical national issues and give advice to the federal government and the public.

- National Center for Science Education <http://ncse.com>.

  Provides information and advice as the premier institution dedicated to keeping evolution in the science classroom and creationism out.

Web Resources Supportive of Intelligent Design

- Discovery Institute <http://www.discovery.org>.

  A pro-ID nonprofit center for national and international affairs. Skeptical of claims for the ability of random mutation and natural selection to account for the complexity of life. Encourages re-examination of the evidence for evolution.

- Michael Behe <http://www.lehigh.edu/~inbios/faculty/behe.html>.

  Lehigh University faculty homepage of one of the prominent figures of the ID movement.

- Phillip Johnson <http://www.touchstonemag.com/leadingedge.php>.

  Monthly column in *Touchstone Magazine* penned by retired UC-Berkeley law professor and founder of the ID movement.

- International Society for Complexity, Information, and Design <http://www.iscid.org>.

  Headed by William Dembski, the ISCID is a cross-disciplinary professional society that investigates complex systems apart from external programmatic constraints like materialism, naturalism, and reductionism. Its aim is to pursue the theoretical development, empirical application, and philosophical implications of information-and-design theoretic concepts for complex systems.

Chapter 6

RECOVERING CONTROVERSY: TEACHING CONTROVERSY IN THE HONORS SCIENCE CLASSROOM

RICHARD ENGLAND

The phrase "teach the controversy" might be taken as the central mantra of honors education. Undergraduate honors classes are often advertised as hothouses of conversation, the essence of a liberal education. Ideally, they are small classes with excellent students, who, guided by passionate, open-minded instructors, tackle fundamental issues and questions through free discussion and debate. The Socratic Method and its myriad variants are celebrated in honors journals and are exemplified in "fishbowls" on hot topics at honors conferences.[1] Attempting to help students learn through reasoned argument, honors instructors often focus on hot topics by teaching the controversy.

The difficulty, of course, is that this slogan has recently been reinvented by those who support the teaching of intelligent design theory in public school science classrooms. In 2005, President George W. Bush, speaking about the debate between evolution and intelligent design, said that "both sides ought to be properly taught," so that people can properly understand the controversy.[2] The strategy was advanced in its current incarnation by the Discovery Institute's Center for Science and Culture in 2002 and remains a key part of the intelligent design campaign.[3] This argument was especially prominent in the 2005 intelligent design trial in Dover, Pennsylvania. In this context then, teaching the controversy becomes a tactical move to introduce alternatives to evolution in the science classroom; those who celebrate controversy as an idealistic pedagogical tool find that their cherished method of teaching has become a pawn in a broader culture war.

This chapter briefly reviews the rhetorical role of controversy in recent attempts to find a place for intelligent design in the public schools, discusses its place in honors education, and attempts to recover teaching the controversy fairly without implicitly taking sides and without letting open-mindedness give more prominence to alternative scientific theories than their scientific merits demand. This approach has the potential to reclaim controversy for honors more completely and to make students better scientists and better citizens in a scientific age.

Intelligent Design—Then and Now

The complexities of nature have long seemed to observers to have been the products of a divine creator. While the psalms of the Bible glorify the Creator's works in nature, one does not see the analogy between human artifacts and the devices of nature made clearly until Plato in the *Timaeus*, Cicero in *De Natura Deorum*, and Galen in *De Usu Partium*. Centuries later, as science and technology emerged as important cultural enterprises in the Middle East and later Western Europe, the analogy between the genius of seventeenth-century clockmakers and the incomparably greater genius of God was made explicitly and repeatedly, with contributions by such major figures as Robert Boyle, John Ray, and Carolus Linnaeus. In the history of evolutionary thought, Archdeacon William Paley often figures as the high-water mark of this kind of argument: his *Natural Theology* (1802) was part of his larger project of Christian apologetics and was intended to answer the skepticism of David Hume, whose *Dialogues Concerning Natural Religion* (1779) cast doubt on the idea that human artifacts were anything like divine productions.[4] Paley, mining the rich vein of discoveries of enlightenment physiology, amassed a dazzling array of examples of the perfection of organic contrivances, focusing on the way that parts were carefully adapted to work together for particular ends. Paley carefully dismantled two arguments: adaptations could occur by chance and that nature could be self-organizing was impossible. He argued instead that the evidence of design in nature demanded a designer.[5] While there were other forms of natural theology, Darwin most directly responded to Paley in his *Origin of Species* (1859), and many of Darwin's contemporaries thought his theory of natural selection had dealt a devastating blow to Paley.

Two centuries after Paley, the same basic argument is made today by intelligent design theorists. Looking at the astounding complexity of cells, some people recognize how they function together to produce an end but cannot see a natural way for this arrangement to come into being. They conclude that an intelligence must be guiding the process.[6] Of course, current intelligent design theory is a sophisticated response to modern neo-Darwinism, and it bolsters its claim to be a scientific alternative to evolution by positing a category labeled "irreducible complexity." That said, the fundamental argument for design essentially offers arguments that have existed for at least two thousand years: the relationship between structure and function is best explained by an intelligence analogous to a designing human intelligence. If imagining how the apparent ingenious designs of nature could have evolved naturally is impossible, then design is the best inference.[7]

This last claim is, of course, contested. Many philosophers and scientists believe that the view is either nonscientific or "dead science."[8] Almost all biologists are united in opposition to this view; even if intelligent design were to be accepted as a scientific alternative to evolution, which critics see as simply a religious position in scientific dress, granting such a minority view in science a place in the high school science curriculum would seem problematic.[9] Yet, by virtue of a campaign of political pressure exerted largely through school boards, the intelligent design movement has succeeded in raising the public profile of their argument to the extent that it is popularly recognized as an alternative to evolution. In this context, claiming to "teach the controversy" has become powerful and problematic. On the surface, teaching both sides of an argument simply seems fair; to do otherwise is to be close-minded. Likewise, the appeal to teach students through argument makes pedagogical sense. Students should be treated as agents in their own education and be given the tools to make up their own minds on controversial issues.

Certainly, science advances through argument. Observations and experiments do not inevitably lead to one theory, and scientists interpret data in different ways. Philosophers of science call this predicament the problem of under-determination. Even the most hard-nosed scientific realists admit that the process of arriving at a scientific truth involves discussion and argument with opponents. After all, science is the work of human beings in historical and social contexts. Nonetheless, while recognizing the importance of controversy within their own disciplines, defenders of evolutionary theory oppose teaching the controversy of intelligent design in the public school science classroom, but this stance leaves them open to charges of dogmatism because only a dogmatist would oppose teaching the controversy. Biologists interested in a legitimate, useful biology curriculum find themselves trapped in an unpleasant rhetorical corner.

Honors and the Traditions of Liberal Education

Controversy, in the broadest sense, is central to a liberal education. Whether discussing literature, arts, politics, or science, educators are constantly making, defending, critiquing, and evaluating claims and evidence. A liberal education, unlike a vocational or professional education, is about learning how to think clearly; it is less about being educated than it is about being educable and developing the skills to learn on one's own.

Given the mandate of many honors programs to serve students from all majors, most programs concentrate their courses in liberal arts or general education requirements shared by all students. Too often students and faculty alike perceive these general education requirements as freshman-year drudgery, a tedious obstacle that must be surmounted before students can get on with their more narrowly focused major courses. That a liberal education is vital to giving students the opportunity to learn how to think and argue is too often forgotten or relegated to institutional boilerplate statements. Honors programs have a role to play here in reminding the university at large that such introductory classes can make a vast difference in the lives and minds of students. The Socratic Method is not about arguing for argument's sake; by laying out and presenting opposing points of view, in all their richness and complexity, students learn how to think about and perhaps approach truth.

But how can educators teach the controversy fairly? Can educators steer between the Scylla of dogmatizing about what may seem to be the right side of the argument and the Charybdis of letting the love of discussion artificially inflate the importance of alternatives? Can teachers guide students through complex debates without so shaking their confidence in the certainty of conclusions as to weaken their faith in reason altogether?

In his *Idea of a University,* John Henry Newman, a great theorist of liberal education, envisioned the liberal arts and sciences as complementary contributors to a well-rounded vision of truth, each with their own sphere but also mutually reinforcing. Fairness requires teaching the controversy over evolution in its entirety and avoiding the perils of dogmatism and relativism while helping students to perceive the true relationship between Darwinism and its critics.

The controversy over intelligent design theory is like many polarized debates in that it can be viewed as a complex network of intertwined issues crossing disciplinary fields. The most prominent range of fields under discussion are of course scientific; ID theorists and their evolutionary opponents discuss the core evidence of cellular biology and biochemistry in great detail. Too often educators give up teaching a controversy because of issues too complex for students to understand. Naturally, the range of scientific questions when it comes to intelligent design is too great to make it possible for students to master the arguments, but even an elementary scientific literacy can be helpful. A nice example of a popular scientific treatment of the subject is the collection of essays published in *Natural History* in April 2002.[10]

This discussion must also incorporate one of the fundamental questions of the philosophy of science: what is science? What is the difference between science and pseudo-science? A basic introduction to these questions could include reviewing Karl Popper's falsificationism as well as critical responses to this kind of demarcation criterion. While many philosophers of science have grown skeptical of attempts to banish intelligent design to the realm of non-science, they have responded to the theory in other ways, examining problems with its logic and its conception of causation.[11]

Perhaps one of the least examined but most important fields in considering this controversy is that of history. To consider the intelligent design controversy without its context makes it easy to imagine that the two sides are as symmetrical in reality as their arguments are in the abstract: X says this and Y says that. Evolution and intelligent design become two characters fighting it out over historical evidence. The introduction of even a smattering of recent history and context can provide information that changes the way students read abstract arguments. For instance, instructors can have students do online research into the supporters of the National Center for Science Education and the Discovery Institute, the two think-tanks whose lawyers have battled in courtrooms across the country. They can also consider the role of previous attempts to teach creationism in the public school science classroom and the way that intelligent design theorists portray their work as non-religious in order to avoid falling foul of the First Amendment. They can examine the locations of the controversy, largely in rural school boards, blogs, and popular magazines but not in scientific journals or societies. Asking where scientific consensus and knowledge are most reliably produced becomes a useful question. Students should consider the similarities between the strategies used by intelligent design theorists and late twentieth-century creation scientists. Ultimately they will want to determine what these historical facts suggest about the nature of the controversy.

Other disciplines also bring different lights to this particular controversy. Insights from rhetoric, theology, political science, educational theory, and even literature contribute to a richer understanding of the intelligent design controversy. Naturally, not even an honors liberal education will be able to touch on all of these fields or absorb the variety of arguments that might be relevant, but by thinking about controversy in a well-rounded way, students will be better able to cautiously and intelligently evaluate claims and think critically about the rhetorical moves used to introduce alternative theories into science classrooms. In short, educators might well teach the controversy about "teach the controversy." A liberal education becomes a hothouse for lively discussion that helps students practice how to think about controversial claims in their complex contexts.

Teach the Controversy Thoroughly

To teach the controversy properly, faculty must teach it thoroughly. Students should not simply consider the two opposed positions and the statements of their respective champions; that might produce an illusion of fairness, but it actually does a disservice to students. Withholding contextual information that would help them to discriminate between the two positions and to understand their respective strengths and weaknesses undermines the thorough teaching of the controversy. Teaching the controversy in this sense becomes an ugly parody of open-mindedness. Applied consistently, it might as well lead to presentations about geocentrism in astronomy classes or phlogiston theory in chemistry classes.

Teaching the controversy cannot absolve teachers from the duty of teaching how to think and should not make them abandon students to the temptations of an easy relativism. This would make education an easy but vapid exercise. Arriving at a clear conclusion at the end of teaching any controversy should be praised, not because students have been taught what to think, but because it may well be evidence that the conclusion has been thought through; in short, it means that students are learning how to think. Socrates always saw argument as a path to truth.

Educators should adhere to the claim that a controversy is complicated at the beginning but not at the end of a discussion. Controversies are jumping-off points for investigating the nature of a complex situation and for understanding its sources and history. Educators must not reduce education to politics; partisan squabbling makes a mockery of the idea of fair and balanced and poisons the wells of learning. If educators teach students that claims of knowledge depend on political convictions, then they have given up on the pursuit of knowledge. That said, students interested in the pursuit of science should know the political context of controversies and should know that there are good scientific answers to objections to mainstream theory as well as complex social and historical reasons driving dissent. Students who understand this dynamic should be better able to defend the value of scientific knowledge claims both as scientists and as citizens.

In high schools, students are sometimes told that they do not have to *believe* in evolution, they just have to know it. Of all the problems of teaching to the test, perhaps this statement is the most cynical and subversive of real learning. It seems calculated to alienate the learner from the point of learning: using discussion and argument to gain understanding and to approach, albeit incrementally, the truth. This strategy can provide a way for students with particular religious beliefs to learn about evolution while holding it at arm's length from their core convictions. But if one does not believe what one knows, does one really know what one believes?

Teaching the controversy, understood as part of the evolving traditions of liberal education, can be recovered and reclaimed as one of the best strategies for teaching and learning. A high school science teacher will probably not have the time to teach any controversy thoroughly, but a professor teaching honors students from all majors in a science liberal education class can provide an essential learning opportunity by doing so.[12] This approach to challenging and divisive issues can help educators avoid mere dogmatism or relativism in the science classroom, can properly situate conflicting claims, and ultimately, can help students to learn how to think about science and its place in their lives.

Bibliography

Behe, Michael. *Darwin's Black Box.* New York: Free Press, 1996.

Brooke, John H. "The Fortunes and Functions of Natural Theology," in *Science and Religion: Some Historical Perspectives.* New York: Cambridge University Press, 1991.

Bumiller, Elizabeth. "Bush Remarks Roil Debate Over Teaching of Evolution." *New York Times*, August 3, 2005. Available online at <http://www.nytimes.com/2005/08/03/politics/03bush.html>.

Comfort, Nathaniel, ed. *The Panda's Black Box: Opening Up the Intelligent Design Controversy.* Baltimore: Johns Hopkins, 2007.

DeWolf, David K., Stephen C. Meyer, and Mark E. DeForrest. *Intelligent Design in Public School Science Curricula: A Legal Guidebook.* Richardson, TX: Foundation for Thoughts and Ethics, 1999. Available online at <http://www.arn.org/docs/dewolf/guidebook.htm>.

Fuller, Steve. *Science vs. Religion? Intelligent Design and the Problem of Evolution.* Cambridge: Polity Press, 2007.

Kitcher, Philip. *Living with Darwin: Evolution, Design, and the Future of Faith.* New York: Oxford University Press, 2007.

Lewens, Tim. *Organisms and Artifacts: Design in Nature and Elsewhere.* Cambridge: MIT Press, 2004.

National Center for Science Education. "Project Steve." Available online at <http://www.ncseweb.org/resources/articles/3541_project_steve_2_16_2003.asp>.

Paley, William. *Natural Theology.* Matthew Eddy and David Knight, eds. New York: Oxford University Press, 2006.

Pennock, Robert, ed. *Intelligent Design Creationism and Its Critics: Philosophical, Theological, and Scientific Perspectives.* Cambridge: MIT Press, 2002.

Zubizaretta, John. "The Teaching and Learning Fishbowl," in *Inspiring Exemplary Teaching and Learning: Perspectives on Teaching Academically Talented College Students.* Larry Clark and John Zubizaretta, eds. Birmingham: NCHC, 2008, 113–7.

Notes

[1]A "fishbowl" is the term given to the technique of beginning a class with a small group, surrounded by the rest of the class; they observe the initial discussion before joining it to explore issues opened in the first part of the conversation by the small group. See John Zubizaretta, "The Teaching and Learning Fishbowl," in *Inspiring Exemplary Teaching and Learning: Perspectives on Teaching Academically Talented College Students,* Larry Clark and John Zubizaretta, eds. (Birmingham: NCHC, 2008), 113–7.

[2]Elizabeth Bumiller, "Bush Remarks Roil Debate over Teaching of Evolution," *New York Times* August 3, 2005: A14. Available online at <http://www.nytimes.com/2005/08/03/politics/03bush.html>.

[3]David K. DeWolf, Stephen C. Meyer, and Mark E. DeForrest, *Intelligent Design in Public School Science Curricula: A Legal Guidebook* (Richardson, TX: Foundation for Thoughts and Ethics, 1999). Available online at <http://www.arn.org/docs/dewolf/guidebook.htm>.

[4]John Brooke. "The Fortunes and Functions of Natural Theology," in *Science and Religion: Some Historical Perspectives* (Cambridge: Cambridge University Press, 1991).

[5]See the introduction to the latest edition of William Paley, *Natural Theology.* Matthew Eddy and David Knight, eds. (New York: Oxford University Press, 2006).

[6]Michael Behe, *Darwin's Black Box.* New York: Free Press, 1996. For a sophisticated analysis of the significance and limits of "artifact talk" in

modern biology, see: Tim Lewens. *Organisms and Artifacts: Design in Nature and Elsewhere* (Cambridge: MIT Press, 2004).

[7]Sander Gliboff, “Paley’s Design Argument as an Inference to the Best Explanation, or Dawkins’ Dilemma,” *Studies in the History and Philosophy of Biology and Biomedical Sciences* 31 (2000): 579–597.

[8]Philip Kitcher, *Living with Darwin: Evolution, Design, and the Future of Faith* (Oxford: Oxford University Press, 2007).

[9]On the numbers of scientists supporting each position and on the practice of creating lists of supporters to establish a truth of a position, see National Center for Science Education, “Project Steve.” Available online at <http://ncse.com/taking-action/project-steve>. Students might also be asked to search for articles on evolution and on intelligent design in scientific journal databases.

[10]This is available online at <http://www.naturalhistorymag.com/darwinanddesign.html>.

[11]See Kitcher’s *Living with Darwin* and many of the essays in Robert Pennock, ed. *Intelligent Design Creationism and Its Critics: Philosophical, Theological, and Scientific Perspectives* (New York: MIT Press, 2002).

[12]Two recent useful texts are Nathaniel Comfort, ed. *The Panda’s Black Box: Opening up the Intelligent Design Controversy* (Baltimore: Johns Hopkins, 2007); and Steve Fuller, *Science vs. Religion? Intelligent Design and the Problem of Evolution* (Cambridge: Polity Press, 2007).

APPENDIX:

Introducing Students to the Controversy over "Teach the Controversy"

In this brief lesson, students from diverse backgrounds can be introduced to the controversy over the strategy of "teaching the controversy." The aim is to get students to see that something as apparently self-evident as allowing critical thinking and letting both sides have their say can be more problematic than it seems. In the articles by Meyer and Santorum below, the strategy of teaching the controversy is defended. The responses by Scott and Branch (leaders of the National Center for Science Education (NCSE)) suggest that there is no real controversy to teach. As students read, instructors should encourage them to consider the following questions.

- What assumptions are the authors making about the "controversy"?
- Where are the articles being published? What does this point of origin suggest about the nature of the controversy?
- What constructive role does controversy have in education? In science?
- Are there situations (real or imagined) where you can see controversy being an obstacle rather than facilitating progress?

As in most honors classes, instructors should act as facilitators and guides. They should help students to understand the non-scientific aspects of what is claimed to be a scientific controversy.

Stephen C. Meyer. "Teach the Controversy." *Cincinnati Enquirer.* March 30, 2002. Web. *Discovery Institute.* <http://www.discovery.org/a/1134>.

Rick Santorum. "A Balanced Approach to Teach Evolution." *The Morning Call.* January 23, 2005. Web. *Discovery Institute.* <http://www.discovery.org/a/2396>.

Eugenie C. Scott and Glenn Branch. "Evolution: What's wrong with 'teaching the controversy.'" *Trends in Ecology and Evolution* 18.3 (2003). 499–502.

—. "The Latest Face of Creationism." *Scientific American* Jan. 2009, 92–99.

Further Viewing

In addition to the readings suggested in the References section, the following video presentations can make a useful contribution to learning about the controversy. All should be accompanied by readings such as those above. Good critical reviews, particularly for *Expelled*, are widely available.

- *Expelled: No Intelligence Allowed*, DVD. Directed by Nathan Frankowski. 2008, Universal City, CA: Vivendi Entertainment, 2008.

  This controversial work outraged evolutionists, but it is an interesting attempt by intelligent design sympathizers to portray themselves as victims. It contains a variety of exaggerated claims, but it also includes some compelling, if sometimes unfair, interviews with leading figures in the controversies. In my experience this film has been an excellent conversation starter.

- *Flock of Dodos: The Evolution-Intelligent Design Circus.* Directed by Randy Olson. 2006, New York, Docurama Films, 2007.

  While somewhat less polished than *Expelled*, this documentary explores evolutionary questions in an insightful, humorous narrative. It humanizes the figures central to the controversy and reminds us that science is not only political but also personal.

- *Judgment Day: Intelligent Design on Trial.* Directed by Gary Johnstone and Joseph McMaster. 2007, Boston, Nova and WGBH Productions, 2007.

  This documentary offers students a close reading of the latest evolutionary court case, in which scientific and philosophical witnesses battled in Dover, Pennsylvania. Because it closely follows the turns of the argument, it reveals some telling weaknesses in the claim that Intelligent Design is scientific rather than religious in nature.

Chapter 7

SCIENCE, POWER, AND DIVERSITY: BRINGING SCIENCE TO HONORS IN AN INTERDISCIPLINARY FORMAT

BONNIE K. BAXTER AND BRIDGET M. NEWELL

Finding the Place for Science in Honors

Because honors programs have been situated in the humanities since their conception in early twentieth-century America, the trajectory of a science curriculum in honors is still in its infancy.[1] A recent scan of large university programs reveals that some major-specific honors programs exist in science, usually in the add-on format: they augment curricula with additional requirements, such as a thesis, to meet the needs of the advanced student. Liberal arts colleges with core honors requirements, however, that are more integrated across disciplines may wrestle with developing science courses that can meet the needs of honors students in all majors.

Typical of many liberal arts colleges, Westminster College's Honors Program grew out of the philosophy department. The program was designed to replace the core of general education requirements with courses that featured team-teaching, an interdisciplinary focus, and an emphasis on primary literature. The initial two-semester science course series stressed the history and philosophy of science and was team-taught by a science professor and a philosophy professor. Several years ago, the professors realized that these courses did not meet important goals in learning science because they lacked experimentation and an emphasis on science as a process as well as discussions of modern science and contemporary science criticism. Since these courses were the only college-level science requirements for honors students who were not science majors, the students were indeed ill-prepared to engage in scientific discourse.

Revision of Westminster's science sequence involved bringing in new faculty and emending the course goals. The first course remained "History and Philosophy of Science," but the second semester presented natural science to the students and engaged them in content from contemporary discoveries. In addition, the honors program was missing a diversity course, a gap the college would soon require everyone to fill. The goal became incorporating diversity into a new science course. A new course, "Science, Power and Diversity" (SPD), enriches the honors curriculum with scientific inquiry in the framework of diversity, using genetics as a thread to bring concepts of science and society to light.

Course Description and Objectives

Science, Power and Diversity:

- Explores the social construction of science-power relationships that influence the discovery and applications of technology.
- Emphasizes seminal scientific issues of the last century and the present.
- Highlights the language and values of science.
- Investigates the status of women and minorities in science.
- Delves into concepts of race and diversity in science.
- Analyzes portrayals of science in the media.
- Stresses science as a force for social change.
- Integrates genetics throughout to explore human diversity at the molecular level.

The class learning goals and objectives are

- To understand science as a powerful social and political force.
- To gain the ability to examine scientific discourse critically.
- To learn concepts in genetics as they apply to human diversity.
- To develop scientific writing skills.
- To learn basic lab techniques and process skills.

(Course readings and topics are located in the Appendix.)

Teaching and Learning Strategies: The First Day and Beyond

Teaching and learning strategies are informed not only by academic backgrounds and interests but also by feminist and other contemporary science criticisms that are integrated throughout the course. One significant aspect of contemporary science criticisms is the focus on problematizing traditional scientific concepts such as value neutrality and objectivity. Another is the focus on the standpoint theory and identity of knowers. In *Whose Science? Whose knowledge? Thinking from Women's Lives*, Sandra Harding outlines the evolution of standpoint theory, focusing on the claim that the achieved identity of the knower shapes the kind of knowledge sought, the methodology selected and utilized, and the knowledge achieved.

Additionally, in the introduction to *Feminism and Methodology*, Harding notes that feminist analysis requires that the knower's position be subject to critical scrutiny in the same way as the research and knowledge he or she achieves:

> The best feminist analysis . . . insists that the inquirer her/himself be placed in the same critical plane as the overt subject matter, thereby recovering the entire research process for scrutiny in the results of research. . . . [In feminist research] we are often explicitly told by the researcher what her/his gender, race, class, culture is, and sometimes how she/he suspects this has shaped the research project—though of course we are free to arrive at contrary hypotheses about the influence of the researcher's presence on her/his analysis. Thus the researcher appears to us not as an invisible, anonymous voice of authority, but as a real, historical individual with concrete, specific desires and interests.[2]

Given that the position of the researcher is highlighted in the exploration of the ways science has historically been used to perpetuate and validate the subordination of women and minorities and the ways that science can be improved, the professors do not present themselves as uninterested, value neutral, and objective. From the first day of class, they acknowledge that their own positions are informed by feminism and political views; as such they are open to criticism as are the issues presented in class. This situation sets the stage for encouraging open, critical discussion and ideally positions students to think critically about bias, value neutrality, and objectivity—issues that are explored throughout the term.

Modeling Learning

In sharing their backgrounds and interests, the instructors explicitly state that they learn from each other and about each other's disciplines while teaching the class, and they intentionally model this learning throughout the term by raising questions and interjecting ideas while the other is presenting or discussing ideas. Their questions demystify the image of the all-knowing philosopher and scientist, reveal their genuine interest in and respect for the other's discipline, and illustrate to students the value of and need for raising questions through the learning process. Given that one of the most basic college-wide learning goals is preparing students to be critical, analytical, and integrative thinkers, the instructors emphasize discussion and questioning in the classroom; modeling this behavior from the first day sets the stage for the future.

Introductions:
Perspective Sharing

Bonnie K. Baxter, PhD (Biology): In introducing herself, she discusses her background in Genetics/Biochemistry and Science Education. She informs the class about her passion regarding issues of women and minorities in science and her work in this area; this information is supplemented with anecdotes about her experiences as a woman in Biochemistry. As a scientist, she was trained to let the data speak for itself and not to apply value or bias to her work. She learned that society at large was incapable of understanding science. In developing this course and reading philosophical discourse about and critiques of science, she learned that scientists have a responsibility to engage the society that funds and is enhanced by the operations of their endeavor. Scientists have a responsibility to consider the social outcomes of their discovery. By introducing her background and the evolution of her views on science and the role of a scientist, she brings the students into this course from the perspective of a scientist who is discovering how social concepts apply.

Bridget M. Newell, PhD (Philosophy): When introducing herself, she clarifies that her PhD is in philosophy, not science. She stresses that her interests in developing, teaching, and revising this class stem from her study of feminist philosophy, feminist science criticism, science ethics, and her dissertation, which integrated these issues in an exploration of scientists' obligations to educate the public. While writing her dissertation, she became interested in the actual workings of science and learned that it was much more interesting than the science she had learned in school. That school science was distanced from the real world, and learning it required memorizing facts, not asking questions. Real science, the science she eventually learned and teaches, focuses on problem solving and working through puzzles: it is intricately connected with society, politics, and ethics. It is a social and political endeavor.

As she learned about this socially situated science via her studies of feminist science criticisms and feminist epistemology, she often wondered, “What would a scientist think of these concerns and criticisms?” This class, she tells students, investigates this question. Together, she and the students learn firsthand how one scientist and perhaps others respond to philosophical analyses and criticisms of science, and because of the lab components, the students also learn to do science along the way.

The background and context provided on the first day allow students to begin to see how their interests and politics influence their work. They also provide an entrée for clarifying that students need not agree with them or the course readings in order to pass the class. What the professors do want to show is that scientists and philosophers do have and take positions both as they do their research and as they teach their classes. With these acknowledgments, the instructors begin the course dialogue in an open, honest manner reflective of many of the issues and theories raised throughout the semester.

Interdisciplinary Approach

The professors deliberately integrate their disciplines throughout the course. As much as possible, they designed each class period to allow for a collaborative discussion based on readings from more than one discipline. If one of them takes the lead in discussions of a particular topic, they construct entry points for the other to raise questions and issues that might arise in the other’s discipline. This process ensures that the content is interdisciplinary. They believe that this interaction helps students to see and to make connections more easily than the tag-team approach, wherein one discipline is the focus for a particular period of time, perhaps one day, week, or segment, until the tag occurs and the other discipline then dominates for a comparable timeframe.

The course segment on homosexuality, for example, incorporates the following readings:

- Brookey, “Beyond the gay gene”
- National Library of Medicine Gene Database, “Homosexuality 1; HMS1”
- LeVay, “A difference in hypothalamic structure between heterosexual and homosexual men”
- Stein, “Choosing the sexual orientation of children”

(See Appendix for full reference information.)

As the class discusses the LeVay article and "homosexuality gene" research, they examine and critique the methods, experiments, and findings as well as the language and its implications. Although Baxter leads this discussion, both of the professors participate throughout the class. In the following class period, they discuss the social, political, and ethical implications of research on homosexuality based on reading the chapter from Brookey.

Brookey's chapter also addresses scientific turf wars regarding whether the study of homosexuality is the domain of genetics and other natural sciences or psychology and the other soft sciences. Brookey's discussion of this aspect of research ties back to earlier discussions of prestige hierarchies among and between scientists raised in Addleson's "The Man of Professional Wisdom."

For this discussion, as well as that of Stein's article on the ethical issues related to the potential to select the sexual orientation of children, Newell takes the lead, but again Baxter draws connections to hard science and highlights insights she has gained from studying the politics of science. This discussion and others with a similar structure reinforce issues raised at the beginning of the course, particularly those highlighting the notion that science is both a social and political endeavor. This looping back to key issues, which strengthens old messages while introducing new ones, is a strategy used throughout the term.

Science-Society Connections

This interdisciplinary perspective allows students to envision the institution of science both from the inside and the outside. To some extent, each side sees science as somewhat elevated in relation to society at large. The students recognize that scientists' language and their depth of understanding about the natural world are not readily accessible to the people who fund or benefit from it. How does this chasm affect the political, social, and ethical impacts of science? Should scientists be concerned with applications of their work? Is science value-neutral? Excerpts from written reflection assignments from the course illuminate student understanding of the discourse on this topic:

> "I believe science influences society because scientists come from society and study things that are of concern to society. So science, in a way, revolves around society."

> "Before I thought that scientists were concerned with their own issues, or more bluntly, self-absorbed."

> "Scientists need to critically think about what the ramifications of what they are studying are and decide from there whether or not the course of study should be pursued."

> "This course has helped me realize that scientists don't just do experiments, but are influenced by many other factors when going about their research. I never really thought about specific biases affecting the way one chooses to perform science."

> "It's quite nice to see a more holistic view of science and scientists. While abandonment of scientific idealism may seem disheartening, the destruction of scientific rigidity actually made science seem more free and hopeful."

> "I still wonder . . . about the value of science as a value neutral system at all. If value neutrality is so impossible for human beings to attain, why, then, do we base our entire society and notions of "reality" on it?"

At the completion of the course, almost every student expresses similar conceptual shifts in their thinking about science and its interplay with societal values. Focused reflections have been a successful way of having the students tune into the development of such ideas.

Interdisciplinary Diversity Focus

The understandings of diversity emphasized in the class are broadly based. In the scientific sense, the term *diversity* is taken almost literally to note an examination of genetic/biological differences and similarities among people in terms of gender, race, ethnicity, geographic origin, and sexual orientation. In the broader sense, the instructors focus on diversity as it is understood in gender, race, and ethnic studies, examining the practitioners and subjects of science and scientific research as related to issues of privilege, oppression, and social justice. They explore the ways science has historically been used to perpetuate social *isms* such as racism, sexism, heterosexism, among others, and they discuss the extent to which science criticisms and politicized epistemologies are positioned to reduce or eliminate these problematic uses of science.

Some of the discussions have explored the question of whether science's part in perpetuating or reinforcing racism and sexism are illustrations of science as usual or of bad science.[3] In these cases, the similarities and differences in positions made for lively class discussion. These discussions also return to pivotal questions: "Do the identity and social position of the scientist shape knowledge sought and found?" "How and to what extent do metaphysical assumptions shape results of scientific research?" and "Does the gender of scientists or their position in the scientific hierarchy shape what becomes the current accepted body of knowledge in science?" Interweaving examples of hard science, such as the work of Barbara McClintock and Rosalind Franklin, and the experiences of these scientists makes discussions of social criticisms of science much richer.

When preparing students to address scientific diversity, the professors provide an overview of Mendelian genetics mainly to review concepts students may have encountered in the past and to set the stage for studying genetics and human diversity. From there the discussion gravitates towards more complex issues like genetic research on homosexuality, the science behind intersex conditions and sex chromosome abnormalities, and genetic research on race. These discussions are accompanied by and complicated by the social, political, and ethical concerns and implications of the research. In some cases the instructors specifically address how science reinforces or shapes social understandings and policies. In other cases, they explore how the scientific and social understandings of the issue differ and raise questions about potential findings of future studies.

When the class examines issues of race and science, they start with historical context, reading two chapters of Stephen J. Gould's *The Mismeasure of Man*. From there they move to Jones' "The Tuskegee Syphilis Experiment: A Moral Astigmatism." The former points to ways science has validated and perpetuated societal assumptions about inequities among races, genders, and classes; the latter allows the professors to layer in ethical concerns related to race, class, and scientific research.

Owens and Claire-King's "Genomic Views of Human History" and Risch, Ziv, and Tang's "Categorization of Humans in Biomedical Research: Genes, Race, and Disease" take the discussion to contemporary research on race. These readings emphasize the fact that more variation exists *within* a certain racial or ancestral population than exists *between* different racial groups. Thus, they position the class to raise the question of whether race is a valid scientific concept. In addressing this issue, students also see how scientific research on race has been and can be used in a positive way, particularly to determine appropriate preventative and treatment options for individuals with different ancestral backgrounds and genders.

Class discussions of contemporary scientific studies of race are also informed by Bamshad and Olsen's "Does Race Exist?" This article raises important questions about the value of race as social and scientific concepts. One class exercise divides students into groups to discuss how the articles might help them to answer the following questions:

- Does race have a biological basis according to Risch?
- Should people of different geographic origins be given identical treatment for diseases?
- How do the genetics of skin color variation relate to current concepts of race, and what implications do they have for racism?
- Is race a valid scientific concept? Is it a valid social concept? Why or why not?

Promoting Various Modes of Thinking

The activity discussed above positions students not only to teach key concepts to each other but also to work together to draw their own conclusions about the implications of scientific research. Within the six-member groups, two students read Bamshad, two read King, and two read Riche so that each pair brings different content to the discussion. Students realize that the articles conveyed different information so they must provide each other with a context for understanding their position.

This activity promotes critical and analytical thinking by providing practice in clarifying and summarizing ideas and oral argumentation. Other course activities promote creative thinking as well as visual thinking. In addition to full-class discussions, small-group discussions, and presentations, the professors stimulate various kinds of thinking with these assignments:

- Design a future scientific study on a topic covered in a recent class discussion; this includes the development of a hypothesis, experimental design, and methods for data collection. After presenting their ideas to the class, students are asked to examine their study for hidden biases or assumptions and potential ethical concerns that could arise from the study.
- Create and explain a visual representation of concepts examined in class. For example, after discussing various understandings of the relationship between science and the world, and scientists and society (relevant reading: Merchant), students illustrate one of these

relationships as it might be seen by Francis Bacon, those with a pre-mechanistic view of the world, or contemporary scientists and environmentalists. After initial concerns about artistic skills are put aside, students become involved in considering options for illustrating the relationship, and in some cases groups create more than one image. The explanations of their illustrations reveal a depth of understanding that may otherwise have been untapped.

- Engage in role-playing to take on and analyze the perspective of those involved with specific scientific problems. Depending on the scenario, roles may include scientists, ethicists, members of society, government officials, and study participants.

Science as a Process

Research reveals that inquiry-based approaches to teaching science are effective for all students.[4] In the SPD course in particular, however, the goal is for honors students to comprehend what scientists do because the discussions necessitate an understanding of the scientific endeavor. Engaging students in the process of science is critical for achieving the goals of the course. To meet this goal, the instructors have developed a series of laboratory exercises that reinforce class concepts and engage students in contemporary techniques while pointing to the pitfalls of bias in antiquated techniques. One set of experiments focuses on isolating, amplifying, and identifying a human genetic sequence with documented variation in the U.S. population. The lab is divided into five sessions, allowing for flexible scheduling in a two-hour class block. Students examine their own DNA and analyze their results, which they then compare with the whole population of students in the class and the U.S. population. This experiment lays the foundation for understanding diversity at the molecular level and variation in genes.

Another lab based on the Gould reading emphasizes measuring the cranial capacity of class members. This task is accomplished using two methods taken from historical experiments. First, students measure the volume of human skulls by pouring lentils into the cavity and calculating the volume of lentils with a graduate cylinder and associating this finding with cranial capacity. Students then measure the skulls of their classmates; they compute the cranial capacity by following a particular protocol and equation. Data are sorted by gender and shared with the class, illustrating clear gender differences in cranial capacity since females on average have smaller brain compartments. This experiment was woven in with Gould's essays, which highlight the use of such studies in "verifying" the intellectual inferiority of women and minority populations. Gould points to other data indicating that skull volume relates to body size but not gender or race *per se*.

Scientific Writing

Scientific writing is another means by which the instructors encourage content integration and enable students to develop at least a partial sense of being a scientist. Given the latter goal, students do many of the assignments in groups, mirroring the practice of scientists who work together to write primary manuscripts or grants. Laboratory reports from the exercises described above give the students the experience of writing as a researcher, paying careful attention to methodology as well as drawing conclusions. They follow a prescribed format although they may choose to focus their analysis on any aspect of the data they collect.

Perhaps the most interesting scientific writing task is the "Media Trace." This assignment highlights the reporting of data in science and compares it to the reporting of discoveries in the mass media. To begin this assignment, students choose a news article reporting a recent scientific study. From this article, they trace the data back to the original science journal article, read the primary literature, and delve into the analysis. Ultimately, the students' papers compare and contrast the two pieces, discussing whether science is shaped by media in ways that are helpful or detrimental to a lay audience attempting to understand the scientific research. This assignment clearly fulfills the goals of introducing students to the primary scientific literature and underscoring the science-society connection.

The last part of the course is spent immersed in a group grant-writing assignment. Illustrating yet another type of scientific writing, this proposal must advocate novel experiments based on previously reported results. Students must access scientific journal articles for the background and methodology of the proposed work. The grant must be associated with the theme of diversity but can be in any field of science. Critical in this assignment is the devotion of in-class time to facilitate group work, discussion of writing and group writing, and assistance in locating and reading articles. The semester culminates with group presentations to the putative funding foundation.

Reflecting, Assessing, and Revising

In addition to positioning students to undertake research to identify potential scientific projects based on existing research and to learn an important kind of scientific writing, the grant project has helped the instructors to identify new course content. For example, one student group proposed a project that built on current biological research on race, genetics, and athletic abilities. Inspired by their project, the instructors enhanced the race segment of SPD with an article that discussed the ethical and social impact of advancing the scientific claim that Africans are better athletes. Next year, the professors plan to use this article in conjunction with science articles describing the muscle fibers of East African marathon runners or the fatigue resistance of South African runners.

The instructors have also used student reflection papers, including the students' final reflections on the class, as resources for deciding whether and how to revise or change class content or the approach to specific topics. The course evolves as students' knowledge bases change and as new science and scientific issues emerge.

Acknowledgements

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Bibliography

Aydelotte, Frank. *Breaking the Academic Lock Step: The Development of Honors Work in American Colleges and Universities.* New York: Harper & Brothers Publishers, 1944.

Bybee, Roger. W. "Teaching Science as Inquiry." In *Inquiring into Teaching Inquiry Learning and Teaching in Science.* Jim Minstrell and Emily H. van Zee, eds. Washington, D.C.: American Association for the Advancement of Science, 2000; 20–46.

Harding, Sandra G. "Is There a Feminist Methodology?" In *Feminism and Methodology: Social Science Issues.* Sandra G. Harding, ed. Indianapolis: Indiana University Press, 1987; 1–14.

Notes

[1]Frank Aydelotte, *Breaking the Academic Lock Step: The Development of Honors Work in American Colleges and Universities.* (New York: Harper & Brothers Publishers, 1944).

[2]Sandra G. Harding, "Is there a Feminist Methodology?" in *Feminism and Methodology: Social Science Issues.* Sandra G. Harding, ed. Indianapolis: Indiana University Press, 1987; 1–14.

[3]Relevant readings include Anderson, Bleier, Tuana, Wilson, and Gould.

[4]For example: R.W. Bybee, "Teaching Science as Inquiry," in *Inquiring into Teaching Inquiry Learning and Teaching in Science*, in J. Minstrell and E.H. Van Zee, eds. Washington, D.C.: American Association for the Advancement of Science, 2000; 20–46.

APPENDIX:

"Science, Power and Diversity" Course Bibliography

These readings represent articles we have used in our course over the last three years, sorted by discussion topic.

Introduction

Anderson, E. (2007) "Feminist epistemology and philosophy of science." *Stanford Encyclopedia of Philosophy.* Retrieved June 25, 2007 from <http://plato.stanford.edu/entries/feminism-epistemology>.

Genetics Science Learning Center (2007). "The basics and beyond." Retrieved June 25, 2007 from <http://gslc.genetics.utah.edu/units/basics/index.cfm>.

Cognitive Authority and Value Neutrality in Science

Addleson, K. P. (1991). "The man of professional wisdom." In M. M. Fonow & J. A. Cook (Eds.) *Beyond Methodology: Feminist Scholarship as Lived Research.* Bloomington, IN: Indiana University Press.

Blumberg, R. B. (1997). "Mendel's paper." *Mendelweb.* Retrieved June 25, 2007 from <http://www.mendelweb.org/>.

Harding, S. (1996). "Rethinking standpoint epistemology: what is strong objectivity?" In E. F. Keller (Ed.) *Feminism and Science.* Oxford, UK: Oxford University Press.

Keller. E. F. (1982) "Feminism and science." *Signs,* 7.3, 589–602.

National Library of Medicine (2007). "The Barbara McClintock papers." *Profiles in Science.* Retrieved June 25, 2007 from <http://profiles.nlm.nih.gov/LL/>.

The Genes of Sexual Orientation and Implications for Society

Brookey, R. A. (2002). "Beyond the gay gene." *Reinventing the Male Homosexual: The Rhetoric and Power of the Gay Gene.* Bloomington, IN: Indiana University Press.

LeVay, S. (1991). "A difference in hypothalamic structure between heterosexual and homosexual men." *Science,* 253, 1034–1037.

Mohr, R. (1995). "Prejudice and homosexuality." In B. MacKinnon (Ed.), *Ethics: Theory and Contemporary Issues* (pp. 218–224). Boston: Wadsworth.

National Library of Medicine (2007). "Homosexuality 1; HMS1". *Online Mendelian Inheritance in Man.* Accession number 306995. Retrieved June 25, 2007 from <http://www.ncbi.nlm.nih.gov/entrez/dispomim.cgi?id=306995>.

Stein, E. (1998). "Choosing the sexual orientation of children." *Bioethics*, 12, 1–24.

Race, Genetics, and Society

Bamshad, M. J. & Olsen, S. E. (2003). "Does race exist?" *Scientific American*. April, 78–85.

Brannigan, M. C. & Boss, J. A. (2001). "Commercialization of the human genome, genetic testing and screening, genetic engineering." *Healthcare Ethics in a Diverse Society* (pp. 256–267), McGraw Hill.

Brannigan, M. C. & Boss, J. A. (2001). "History and resurgence of eugenics: the human genome project." *Healthcare Ethics in a Diverse Society* (pp. 249–255), McGraw Hill.

Fouad, M. N., Partridge, E., Wynn, T., Green, B., Kohler, C. & Nagy, S. (2001). "Statewide Tuskegee alliance for clinical trials—a community coalition to enhance minority participation in medical research." *Cancer,* 91, 237–241.

Gould, S. J. (1981). "American polygeny and craniometry before Darwin: blacks and Indians as separate, inferior species." *The Mismeasure of Man: The Definitive Refutation to the Argument of the Bell Curve* (pp. 62–104). New York: W.W. Norton & Company.

Gould, S. J. (1981). "Measuring heads: Paul Broca and the heyday of craniology." *The Mismeasure of Man: The Definitive Refutation to the Argument of the Bell Curve* (pp. 105–141). New York: W.W. Norton & Company.

Jones, J. (1993). "The Tuskegee Syphilis experiment: a moral astigmatism." In S. Harding (Ed.), *The Racial Economy of Science: Toward a Democratic Future* (pp. 275–286). Indianapolis, IN: Indiana University Press.

Mead, A. T. P. (1996). "Genealogy, sacredness, and the commodities market." *Cultural Survival Quarterly*, 20.2, Retrieved June 25, 2007 from <http://www.cs.org/publications/Csq/csq-article.cfm?id=1585>.

Morrison Institute for Population and Resource Studies, Stanford University. (1999). "Human genome diversity project FAQ." Retrieved June 25, 2007 from <http://www.stanford.edu/group/morrinst/hgdp/faq.html>.

Mosely, A. (2003). "Racial difference in sports: what's ethics got to do with it?" In J. Boxill (Ed.), *Sports Ethics: An Anthology* (p. 297–303). Malden, MA: Blackwell.

Outlaw, L. T., Jr. (1999). "On race and philosophy." In S. E. Babbitt & S. Campbell (Eds.) *Racism and Philosophy*. New York: Cornell University Press.

Owens, K. & Claire-King, M. (1999). "Genomic views of human history." *Science.* 286, 451–453.

Risch, N. Burchard, E., Ziv, E. & Tang, H. (2002). "Categorization of humans in biomedical research: genes, race, and disease." *Genome Biology,* 3, 2007.1–2007.12.

Sankar, P. & Khan, J. (2005). "BiDil: race medicine or race marketing?" *Health Affairs-Web Exclusive.* Retrieved June 25, 2007 from <http://minority-health.pitt.edu/archive/00000275/01/BiDil-_Race_Medicine_Or_Race_Marketing.pdf>.

Skloot, R. (2000). "Henrietta's dance." *Johns Hopkins Magazine.* Retrieved June 25, 2007 from <http://www.jhu.edu/~jhumag/0400web/01.html>.

Thomas, S. B. & Quinn, S. C. (1991) "The Tuskegee Syphilis study, 1932 to 1972: implications for HIV education and AIDS risk education programs in the Black community." *American Journal of Public Health,* 81, 1498–1504.

University of Virginia Health System. (2007). "Bad blood: the Tuskegee Syphilis study." Retrieved June 25, 2007 from <http://www.healthsystem.virginia.edu/internet/library/historical/medical_history/bad_blood/>.

Gender and Science

Association for Women in Science. (2007). *Statistics.* Retrieved June 25, 2007 <http://www.awis.org/news/statistics.html>.

Barbercheck, M. (2001). "Mixed messages: men and women in advertisements in *Science.*" In M. Wyer (Ed.) *Women, Science, and Technology: A Reader in Feminist Science Studies* (pp. 117–131). New York: Routledge.

Barres, B. A. (2006). "Does gender matter?" *Nature* 442, 133–6.

Bleier, R. (1984). "Sociobiology, biological determinism and human behavior." *Science and Gender: A Critique of Biology and Its Theories on Women* (Chapter 2). Oxford: Pergamon Press.

Fausto-Sterling, A. (1993). "The five sexes." *Sciences,* 33, 20–26.

Fausto-Sterling, A. (2000). "The five sexes, revisited." *The Scientist,* 18–24.

Franklin, R.E. & Gosling, R.G. (1953). "Molecular configuration in sodium thymonuclate," *Nature,* 171, 740–741.

Jegalian, K. & Lahn, B. T. (2001). "Why the Y is so weird." *Scientific American.* February, 56–61.

Lewis, R. (2000). "Reevaluating sex reassignment." *The Scientist,* 14, 6.

Martin, E. (1991). "The egg and the sperm: how science has constructed a romance based on stereotypical male-female roles." *Signs,* 16, 485–501.

Meinert, C. L. (2001). “The inclusion of women in clinical trials.” In M. Lederman & I. Bartsch (Eds.), *The Gender and Science Reader* (pp. 303–306). NY: Routledge.

Public Broadcasting System: American Experience. (2002). *The Pill.* Retrieved June 25, 2007 from <http://www.pbs.org/wgbh/amex/pill/>.

Rich, J, and Roe, M. (2002). “A poor man’s plight: uncovering the disparity in men’s health.” W.K. Kellogg Foundation. Battle Creek, MI. Retrieved June 25, 2007 <http://minority-health.pitt.edu/archive/00000038/>.

Summers, L. H. (2005). “Letter from President Summers on women in science.” Retrieved June 25, 2007 from <http://www.president.harvard.edu/speeches/2005/womensci.html>.

Summers, L. H. (2005). “Remarks at NBER conference of diversifying the science and engineering workforce.” Retrieved June 25, 2007 from <http://www.president.harvard.edu/speeches/2005/nber.html>.

Tuana, N. (1993). “Brains or wombs: sex and education.” *The Less Noble Sex: Scientific, Religious, and Philosophical Conceptions of Women’s Nature* (pp. 74–78). Indianapolis: Indiana University Press.

Watson, J. & Crick, F. (1953). “A structure for deoxyribose nucleic acid.” *Nature* 171, 739–740. (annotated version retrieved June 25, 2007 from <http://www.exploratorium.edu/origins/coldspring/printit.html>).

Wenneras, C. & Wold, A. (1997). “Nepotism and sexism in peer review.” *Nature* 387, 341–343.

Science Writing

Hacker, D. (2007). “Sciences.” *Research and Documentation Online.* Retrieved June 25, 2007 from <http://www.dianahacker.com/resdoc/sciences.html>.

The Foundation Center. (2007). *Proposal writing short course.* Retrieved June 25, 2007 from <http://fdncenter.org/learn/shortcourse/prop1.html>.

SECTION III:

SCIENCE AND MATHEMATICS IN HONORS FOR THE NON-SCIENCE STUDENT

Chapter 8

HONORS SCIENCE FOR THE NON-SCIENCE-BOUND STUDENT: WHERE HAVE WE GONE WRONG?

BRADLEY R. NEWCOMER

The State of Science Education in Today's Colleges

Today's college students are not developing an enduring understanding of the science and mathematics subject materials they are supposedly learning in college. According to Lord and Bavishkar, Benjamin Bloom first noted this trend in a 1989 *New York Times* report; Bloom states that there is a "sharp gap emerging between the ability of students to learn basic principles and their ability to apply knowledge or explain what they learned."[1] Interestingly, this trend has reached a critical level today and transcends all institutional types and sizes. Lord and Bavishkar attribute these disturbing trends to the following three factors:

- How college science and math curricula are set up;
- How college professors teach science and math courses;
- How college professors assess student learning in science and math courses.

In terms of the curricular set-up, college science and math courses are traditionally developed and taught as a series of isolated specialized courses. These courses are traditionally not integrated well with one other, either within a discipline or between disciplines. This curricular arrangement fosters a compartmentalized and fragmented knowledge set in today's students. This in turn reduces the student's ability to apply knowledge from these isolated courses to the complex issues and problems that society faces today.

In terms of how courses are taught, the traditional lecture format in most science and math courses reduces student learning and creates a learning environment in which students passively rely on experts or instructors to deliver course content and information to them. Students do not actively participate in this environment unless instructors take great care to include supplemental engagement activities such as discussion, debates, experiments, or field experiences. This traditional format for delivering content is driven more by cost considerations and less by learning effectiveness and has fostered a generation of passive learners divorced from any responsibility for their own learning and education. This system has bred students who expect to have the course materials miraculously imparted to them without any work on their part to actively learn the material. When combined with poor assessment practices, this passive-learning environment encourages students to memorize rather than comprehend course content. Furthermore, as Lord states, "rarely are students asked to apply information being taught to different situations, to give examples of items in the lesson outside the books listings, or to develop their own investigative activities in the lab."[2] Most agree that this strategy is not the most effective way to develop true understanding of science and mathematics concepts. A better option would be to integrate many forms of instruction as well as intentional content integration throughout a student's undergraduate education instead of fostering a system of isolated and independent courses based on certain subject areas or disciplinary fields

The traditional student assessment methods for science and mathematics require students to regurgitate large amounts of information and factual knowledge. This practice emphasizes the ability of students to memorize large amounts of information, regardless of whether they truly understand the material.[3] Furthermore, traditional assessment methods rarely ask students to apply their knowledge to real-world problems or to integrate information from multiple courses into a solution. Overall, this traditional method of student-learning assessment emphasizes memorization instead of comprehension of the course content.

Overall, these three issues have been an outgrowth of the "content driven, professional indoctrination" model of science and math education developed in the 1950s and 1960s.[4] Developed during the height of the cold war and space race to train America's professional scientists, this model trains specialists rather than generalists. Furthermore, the current realities in extramural funding for higher education has created a publication and grant system that rewards these types of specialists and has given rise to the environment operating at most research universities. Unfortunately, in this type of science education model, students are not given the opportunity to draw connections between the different scientific disciplines nor between the sciences and humanities. Further, this educational model does not give students an opportunity to discover the big pictures in science nor does it inspire them to realize how science, math, and the humanities are all important to modern society and the human condition. In today's world, this model will not work and certainly should not be tolerated in honors educational opportunities for non-science-bound students.

The remainder of this chapter will focus on these three dysfunctional areas of today's science and math education as it pertains to honors experiences for non-science majors in science and math courses. This chapter will also provide a conceptual framework to address these issues in addition to briefly discussing the general characteristics of honors-level science courses for non-science majors.

General Characteristics of Honors-Level Science and Math Courses for Non-Science Majors

Honors-level science courses for non-science majors should be different from comparable non-honors courses in three ways:

- Honors science courses for non-majors should have different *Philosophical Goals* from their non-honors equivalent courses.
- Honors science courses for non-majors should have different *Content Delivery Methods and Course Learning Experiences* from their non-honors equivalent courses.
- Honors science courses for non-majors should have different *Assessment Methods* from their non-honors equivalent courses.

Philosophical Goals

For non-science majors, these honors-level science courses should connect science and math to the social, political, and ethical areas of humanity in an integrated, generalized, multi-disciplinary set of courses. These courses should provide a "unifying explanation of many separate areas of study."[5] Institutions need to think about and reevaluate their science and math curricula in this way. Unfortunately, these reemerging trends in multi- and interdisciplinary education often focus on the general education and core curricular courses taken during the initial years of an undergraduate's education. One option would be to create a series of upper-level multi-disciplinary courses focused on integrating various science and math concepts with courses in the non-science and non-math departments. This could be done as a series of courses spread across the continuum of a student's undergraduate education. Alternatively, these courses could be linked together within selected semesters along a student's undergraduate education to form a series of multi-disciplinary learning communities. Philosophically, these efforts would create an institutional focus that emphasizes scientific and quantitative literacy for all undergraduate students regardless of major or academic discipline.

Furthermore, in multi-disciplinary honors-level science and math courses, the instructors should design activities and work that produce a deep understanding of the subject matter. These activities should emphasize experiential-learning opportunities over activities in which students merely assimilate information. These courses should also use tasks, activities, and assessment methods that emphasize higher levels of learning, such as application, analysis, synthesis, and evaluation, as opposed to the lower levels of knowledge and comprehension that most courses focus on today.

These non-major honors-level science and math courses should also focus on developing the students' quantitative and scientific literacy.[6] This objective is completely in-line with the 1989 report of the American Association for the Advancement of Science (AAAS) and the 1996 report of the National Research Council (NRC), which recommended that science curricula focus on the "nature of science" and the development of "scientific literacy" in students.[7] Consequently, honors-level science and math courses should improve students' quantitative literacy through increasing their everyday understanding of mathematics as a language that expresses relationships and patterns. Too often math courses concentrate on the mechanics of solving specific types of problems and lose sight of the way average citizens use basic mathematical information and skills, such as understanding basic ratios and graphical representations of data and interpreting basic statistical relationships. These courses should also increase students' understanding of the scientific method, their understanding of the nature of data and evidence, and their ability to assess the reliability of data. In the end, students should be able to distinguish quantitative and scientific evidence from political propaganda and pseudoscience. The ability to engage these scientific and quantitative literacy issues will be one of most important skills the next generation of students will learn.

Content Delivery Methods and Course Learning Experiences

Instructors of honors-level science and math courses for the non-major should consider balancing traditional lectures with complementary teaching approaches. For example, instructors should structure courses to allow for greater self-exploration and self-discovery of the course's main concepts and content.[8] One approach would be using context-based and real-world problems and examples.[9] Case-study analyses and field-work activities are ideal for fostering these types of learning experiences in a science classroom.[10] One example of a case-study approach in physics would be using data from actual vehicle accident reports to predict if a car was traveling at the speed limit prior to the accident by performing a simplified forensic analysis of the accident scene data. The use of real data and real-world situations can stimulate a student's interest and focus their attention long enough for them to start studying and applying the basic concepts being taught in the class. Unfortunately, all too often instructors settle for idealized laboratory exercises and experiments. An example of such an idealized exercise would be an introductory physics lab experiment in which students measure various parameters on an aluminum sled sliding on an air track. Although this type of laboratory experiment is simple to implement and does allow the demonstration of some basic principles of motion and momentum, such activities generally bore the students and destroy their ability to see any relevance of the course content to their existence or sphere of concern. It is hard to imagine a student who would find the air track experiment more relevant or enjoyable than applying some of the same theoretical concepts to the simplified forensic analysis of vehicle accident data. In today's educational environment, the value of doing a set of idealized laboratory experiments for the sake of teaching the students the scientific method is questionable. Without much difficulty, real world situations, problems, and data can be integrated into many science and math courses.[11]

Another possibility for bringing the real-world into the science and math classroom is to increase the integration of service-learning activities and opportunities into these honors-level science and math courses.[12] A valuable resource for linking science with civic engagement is the Science Education for New Civic Engagement and Responsibility (SENCER) initiative.[13] SENCER, a program of the National Center for Science and Civic Engagement, was initiated in 2001 by the National Science Foundation to help educators and to provide resources for incorporating civic engagement into the science classroom. The types of activities and resources from the SENCER initiative not only enhance the relevance of the science and math content but also increase the students' civic engagement and exposure to current societal problems and opportunities.[14] Furthermore, these types of learning activities and opportunities provide a natural bridge from the sciences and math to the humanities. Through civic engagement and service-learning activities, students attain an enhanced understanding of how science and math are important to modern society and related to their non-science fields of study. In the end, these learning experiences will increase the motivation of non-major students to study and learn science and math. Furthermore, students will develop an increased realization of the importance of these science and math courses to modern society and to the human condition.

Assessment Methods

Assessments of student learning in the sciences needs to rely less on testing for fact recitation. Course assessments should instead focus on assessing the students' understanding of the scientific method and their ability to identify and explain the values and limitations of their methodologies. Furthermore, assessment methods should focus on the students' abilities to interpret data and apply these interpretations to contemporary problems in the real world. Course assessments in these types of honors-level science and math courses should minimize quizzes and exams while concentrating on projects and written and oral reports. Where possible, these courses should emphasize team projects to foster collaboration, cooperation among peers, and learning communities. Assessments of these projects should be based on reports, evaluations, and summaries of their projects, and activities and exercises should include an opportunity for reflection. These reflective activities can enhance these courses if they focus on the scientific and quantitative processes. Students should analyze their projects and activities for limitations and areas for future improvements, even suggesting areas that could be done differently if the experience or activity were to be repeated in the future. Assessments in these courses should also encourage frequent feedback from peers, mentors, and teachers and should provide opportunities for students to revise conclusions and reflective components when necessary. Instructors should base their overall grades and assessments more on the students' analyses and presentations of their experiential-learning encounters and less on students' abilities to recite chapters full of factual content or on their mechanical skills when solving idealized mathematical problems. In the end, the goal for these courses should be teaching students how to apply the course content and knowledge and then assessing them based on their abilities to work with real-world problems and situations.

Final Thoughts

By concentrating on new philosophical goals, content delivery methods, learning experiences, and assessment methods, educators have the opportunity to create a new generation of honors-level science courses for non-majors. They have the opportunity to move away from the current educational model that promotes extreme specialization and to return to an integrated and more generalized approach to teaching science and math. Today's curricula should concentrate on the inter- and multi-disciplinary nature of science and math and their relationship to the humanities and non-science disciplines. Lower-level courses should focus on the processes of science (i.e., the scientific method) and on interpreting and understanding scientific data and discoveries (i.e., scientific and quantitative literacy). Today's courses for non-science majors should focus more on real-world applications and less on theoretical ideas. Overall, undergraduate courses in science and math for the non-majors should focus less on details and more on teaching students how to use scientific data and ideas in their own lives as they encounter real-world problems and issues.

This focus should produce students who are better able to draw connections among the different scientific disciplines and to math and the humanities. Educators have the opportunity to reinvent an educational model that emphasize students' abilities to think critically in terms of quantitative and scientific literacy issues. Instructors can also increase students' motivation by engaging them actively in the learning process and by bringing the real world back into these science and math courses. Two quotations summarize these ideas:

> "I hear and I forget, I see and I remember, *I do and I understand.*" (Confucius, 551–479 B.C.)[15]

> "I never teach my pupils; I only attempt to provide the conditions in which *they* can learn." (Albert Einstein)[16]

These quotations articulate the ultimate goals for the next generation of honors-level science and math courses. Educators should create an environment and orchestrate conditions in which students learn by doing. Only through participating in the scientific method, evaluating the outcomes, analyzing the limitations, and applying the results to real-world scenarios and situations will this next generation of students truly learn, understand, and develop an appreciation for science and mathematics.

Bibliography

Alles, David L. "Synthesizing Scientific Knowledge: A Conceptual Basis for Non-Majors Science Education." *Journal of College Science Teaching* 33, no. 6 (2004): 36–39.

American Association for the Advancement of Science. *Project 2061: Science for All Americans.* Washington, D.C.: AAAS, 1989.

Avard, Margaret. "Civic Engagement in the Science Classroom." *Journal of College Science Teaching* 36, no. 3 (2006): 12–13.

Bennett, Julie, Fred Lubben, and Sylvia Hogarth. "Bringing Science to Life: A Synthesis of the Research Evidence on the Effects of Context-Based and STS Approaches to Science Teaching." *Science Education* 91, no. 3 (2007): 347–370.

Camill, Philip. "Case Studies Add Value to a Diverse Teaching Portfolio in Science Courses." *Journal of College Science Teaching* 36, no. 2 (2006): 31–37.

Caprio, M.W. "Designing Nonmajors' Science Courses—Is there a Better Way?" *Journal of College Science Teaching* 29, no. 2 (1999): 134–137.

Confucius. BrainyQuote.com, Xplore Inc, 2010. <http://www.brainyquote.com/quotes/quotes/c/confucius136802.html>. Accessed April 19, 2010.

Feldberg, Ross. "Biosocial Problems in Contemporary America: A Course on the Use and Misuse of Scientific Knowledge." *Journal of College Science Teaching* 36, no.7 (2007): 35–39.

Gallagher, James J. "Teaching for Understanding and Application of Science Knowledge." *School Science and Mathematics* 100, no. 6 (2000): 310–318.

Hammer, Christy, and Val Dusek. "Science Studies Across General Education: A Broader View of Scientific Literacy." *Peer Review* (2005): 21–22.

Hohman, James, Paul Adams, Germaine Taggart, John Heinrichs, and Karen Hickman. "A 'Nature of Science' Discussion: Connecting Mathematics and Science." *Journal of College Science Teaching* 36, no. 1 (2006): 18–21.

Lord, Thomas, and Sandhya Baviskar. "Moving Students from Information Recitation to Information Understanding: Exploiting Bloom's Taxonomy in Creating Science Questions." *Journal of College Teaching* 36, no. 5 (2007): 40–44.

Lord, Thomas. "Teach for Understanding before the Details Get in the Way." *Journal of College Science Teaching* 36, no. 6 (2007): 70–72.

Mauldin, Robert F., and Larry W. Lonney. "Scientific Reasoning for Nonscience Majors." *Journal of Science Teaching* 28, no. 6 (1999): 416–421.

National Research Council. *Teaching for Understanding and Application of Science Knowledge from the National Science Education Standards.* Washington, D.C.: National Academy Press, 1996.

Science Education for New Civic Engagement and Responsibility Website. Available online at <http://www.sencer.net>.

Tolman, Deborah A. "A Science-in-the-Making Course for Non-Science Majors." *Journal of College Science Teaching* 29, no. 1 (1999): 41–46.

Walter, G.A., and S.E. Marks, *Experiential Learning and Change.* New York: John Wiley and Sons, 1981.

Wieder, Will. "Science as Story: Communicating the Nature of Science through Historical Perspectives on Science." *The American Biology Teacher* 68, no. 4 (2006): 200–205.

Wilkins, Jess L. M. "Preparing for the 21st Century: The Status of Quantitative Literacy in the United States." *School Science and Mathematics* 100, no. 8 (2000): 405–418.

Yadav, Aman, Mary Lundeberg, Michael DeSchryver, Kathryn Dirkin, Nancy A. Schiller, Kimberly Maier, and Clyde Freeman Herreid, "Teaching Science with Case Studies: A National Survey of Faculty Perceptions of the Benefits and Challenges of Using Cases." *Journal of College Science Teaching* 37, no. 1 (2007): 34–38.

Notes

[1]Thomas Lord and Sandhya Baviskar, "Moving Students from Information Recitation to Information Understanding: Exploiting Bloom's Taxonomy in Creating Science Questions," *Journal of College Teaching* 36, no. 5 (2007): 40–44.

[2]Thomas Lord, "Teach for Understanding Before the Details Get in the Way," *Journal of College Science Teaching* 36, no. 6 (2007): 70–72.

[3]James J. Gallagher. "Teaching for Understanding and Application of Science Knowledge," *School Science and Mathematics* 100, no. 6 (2000): 310–318.

[4]Lord and Baviskar, "Moving Students."

[5]David L. Alles, "Synthesizing Scientific Knowledge: A Conceptual Basis for Non-Majors Science Education," *Journal of College Science Teaching* 33, no. 6 (2004): 36–39.

[6]Will Wieder, "Science as Story: Communicating the Nature of Science through Historical Perspectives on Science," *The American Biology Teacher* 68, no. 4 (2006): 200–205; Jesse L. M. Wilkins, "Preparing for the 21st Century: The Status of Quantitative Literacy in the United States," *School Science and Mathematics* 100, no. 8 (2000): 405–418; M.W. Caprio, "Designing Nonmajors' Science Courses—Is There a Better Way?" *Journal of College Science Teaching* 29, no. 2 (1999): 134–137; James Hohman, Paul Adams, Germaine Taggart, John Heinrichs, and Karen Hickman, "A 'Nature of Science' Discussion: Connecting Mathematics and Science," *Journal of College Science Teaching* 36, no. 1 (2006): 18–21; Ross Feldberg, "Biosocial Problems in Contemporary America: A Course on the Use and Misuse of Scientific Knowledge," *Journal of College Science Teaching* 36, no. 7 (2007): 35–39; Deborah A. Tolman, "A Science-in-the-Making Course for Non-Science Majors," *Journal of College Science Teaching* 29, no. 1 (1999): 41–46; Christy Hammer and Val Dusek, "Science Studies Across General Education: A Broader View of Scientific Literacy," *Peer Review* (2005): 21–22.

[7]American Association for the Advancement of Science (AAAS), *Project 2061: Science for all Americans* (Washington, D.C.: AAAS, 1989); National Research Council (NRC), *Teaching for Understanding and Application of Science Knowledge from the National Science Education Standards.* (Washington, D.C.: National Academy Press, 1996).

[8]Lord and Baviskar, "Moving Students."

[9]Wieder, "Science as Story;" Julie Bennett, Fred Lubben, and Sylvia Hogarth, "Bringing Science to Life: A Synthesis of the Research Evidence on the Effects of Context-Based and STS Approaches to Science Teaching," *Science Education* 91, no. 3 (2007): 347–370.

[10]Aman Yadav, Mary Lundeberg, Michael DeSchryver, Kathryn Dirkin, Nancy A. Schiller, Kimberly Maier, and Clyde Freeman Herreid, "Teaching Science with Case Studies: A National Survey of Faculty Perceptions of the Benefits and Challenges of Using Cases," *Journal of College Science Teaching* 37, no. 1 (2007): 34–38.

[11]Wieder, "Science as Story"; Bennett, Lubben, and Hogarth, "Bringing Science to Life"; Yadav, et.al., "Teaching Science with Case Studies;" Philip Camill, "Case Studies Add Value to a Diverse Teaching Portfolio in Science Courses," *Journal of College Science Teaching* 36, no. 2 (2006): 31–37; Robert F. Mauldin and Larry W. Lonney. "Scientific

Reasoning for Nonscience Majors," *Journal of Science Teaching* 28, no. 6 (1999): 416–421.

[12]Margaret Avard, "Civic Engagement in the Science Classroom," *Journal of College Science Teaching* 36, no. 3 (2006): 12–13.

[13]Please see Chapter 4 of this Monograph for further information on this program.

[14]"Science Education for New Civic Engagement and Responsibility (SENCER)." Available online at <http://www.sencer.net>.

[15]Confucius. BrainyQuote.com, Xplore Inc, 2010. <http://www.brainyquote.com/quotes/quotes/c/confucius136802.html>, accessed April 19, 2010.

[16]G.A. Walter and S.E. Marks, *Experiential Learning and Change* (New York: John Wiley and Sons, 1981).

Chapter 9

ENGAGING THE HONORS STUDENT IN LOWER-DIVISION MATHEMATICS

MINERVA CORDERO, THERESA JORGENSEN, AND
BARBARA A. SHIPMAN

Mathematics in the Honors Curriculum

In 2010, the National Collegiate Honors Council published a set of twelve recommendations for fully developed honors colleges.[1] Those that refer to curriculum suggest that the program offer significant course opportunities across all four years of study, that the honors curriculum constitute at least twenty percent of a student's degree program, and that an honors thesis or project be required. Because mathematics is a core academic subject in most undergraduate degree programs, offering lower-division honors courses in mathematics is an appropriate means to increase the options students have for earning honors credits in courses that will be required for their degree program.

The lower-division honors courses in mathematics offered every year at the University of Texas at Arlington (UT Arlington) are an honors mathematics course for non-science majors and Honors Calculus I and II for science, technology, engineering, and mathematics majors. Common questions that arise about teaching honors mathematics courses include the following: What mathematics should be taught in a course for honors liberal arts majors, and how can it be taught to provide an honors experience? How do instructors make a calculus course honors? What should instructors expect from the students? After addressing characteristics and expectations of honors students, this article discusses ideas for creating meaningful honors experiences in lower-level honors courses in mathematics, both for non-science majors and for science majors. We consider first an honors course in mathematics for liberal arts majors and second, an honors course in calculus.

The Honors Student

In honors calculus the students are typically freshmen who are math or science majors. In contrast, students pursuing liberal arts majors may be taking their final mathematics course before graduation. In both cases, however, by designating themselves as honors students, they have invoked the following high expectations: Honors students should have the desire and motivation during their undergraduate years to educate themselves beyond the requirements of the degree they seek. They should want to understand what they study in great depth and within a broad context with a vision toward developing their career and becoming lifelong learners. Honors students should also be actively engaged in their learning and take ownership of their education; they should be in a class because they want to be there.

In new groups of honors students in lower-division mathematics courses, these qualities might not yet be well developed: the students might not be ready to actively learn on the first day of class. The qualities listed above must be taught and nurtured in the students as part of an honors education. Honors students, like other students, have heavy course loads and commitments outside of classes that may tempt them to not put enough time into homework, skip class occasionally, and not take the initiative on their own to excel to the best of their capabilities. Instructors of honors courses need to be aware of these pressures on the students and be armed with instructional strategies that will develop the qualities expected of them.

Expectations of an Honors Course in Mathematics

The following are goals for any honors course in mathematics. The institution offering these honors sections should carefully consider the appropriate maximum class size that will allow these goals to be accomplished effectively.

Ownership

Honors students should become the owners of the mathematics they study. They must take the initiative in deciding whether mathematical statements are true or false, whether a question is worthy of investigation or not, and how new mathematical concepts should be formally defined.

Communication

In an honors course, students should communicate and defend their arguments, both formally and informally and both orally and in writing, to the instructor and to their classmates.

Greater Maturity

An honors course should expand the students' view of what mathematics is and how to think about it so that, after completing the course, students can look back and be amazed at how their mathematical maturity has developed.

Broader Context

An honors course in mathematics should give the students a perspective on how the subject has developed and how it is still evolving. This can include how other disciplines have influenced the development of mathematics or how mathematics has driven advances in other sciences or in the fields of mathematics.

Mathematics for the Honors Liberal Arts Student

Many students, even honors students, may enter mathematics courses with a fear of the subject. In UT Arlington's mathematics course designed for honors liberal arts students, entitled Honors Liberal Arts Mathematics, fear of mathematics is the invisible gorilla in the room at the beginning of the semester. The majors most represented in this class tend to be English and journalism, and, as a whole, the students do not project much confidence in their mathematical ability. The course is designed, however, to allow students to discover and explore topics in mathematics that may be completely foreign to them and may not even seem to be mathematics at first glance. Because of this structure, the students transcend many of their mathematical hang-ups and open their minds to the possibility of enjoying mathematics. The mathematical situations they study are often simple to state but incredibly rich in their depth. The students encounter and interact with mathematical areas that open problems that are understandable by novices. Faculty members expect these students to do mathematics that they initially believe to be far beyond their abilities, and it is amazing how they rise to the occasion.

Honors mathematics for liberal arts majors offers the opportunity to study all sorts of mathematics that are accessible to students at the college freshman level but have been omitted from the high school mathematics curriculum. Books used as sources for topics, discovery problems, and projects include *The Heart of Mathematics: An Invitation to Effective Thinking*, *To Infinity and Beyond*, and *Knots and Surfaces: A Guide to Discovering Mathematics*.[2] Readings are supplemented with articles from journals such as the *Mathematics Magazine,* the *American Mathematical Monthly,* and the *Notices of the AMS* and occasionally an interesting movie on mathematics. Some of the topics that can be included are graph theory, knot theory, the mathematics of voting, fair division, cryptography and coding theory, Fibonacci numbers, the Golden Rectangle, and notions of infinity.

The course also includes a few topics that the students have either studied or heard of, but it treats them in a new way. The following project is a good starting point to give the students a full flavor of the course.

Activity 1: The Pythagorean Theorem

After students are reminded of the famous Pythagorean Theorem, the first activity integrates two well-known geometric arrangements that provide visual ways of seeing why the Pythagorean Theorem is true. This geometric approach is taken in many textbooks, including *The Heart of Mathematics: An Invitation to Effective Thinking*[3] by Burger and Starbird (2010).

The Statement

This exercise begins with the class being asked to state the theorem and provide a few examples where the lengths of the sides are integers (Pythagorean triples). Students invariably recall studying the Pythagorean Theorem, and many of them are able to state it and use it correctly. The instructor can prompt the class to suggest finding such triples by listing the squares of the first fifteen or so positive integers and checking to see which two squares have a sum that is equal to another. The instructor then asks the class whether the theorem holds for right triangles where the lengths of one or more sides are not integers and, if so, to give some examples.

The Question

The challenge now comes when the class is asked: "How do you know that the Pythagorean Theorem is true? Is there a right triangle for which it does not work?" For many students, this moment may be the first time they have considered the question of *why* in mathematics. Now, not only are they confronting the question, but they must discover a solution themselves and defend their answers. The class as a whole should have a few minutes to think about this question. The purpose of this phase is for students to realize that throughout their study of mathematics, they have been using formulas without understanding why the formulas are true. They should now be curious to find an explanation for the Pythagorean Theorem.

Group Discovery

The students gather in groups of three to four around tables and work with cutouts to devise a geometric proof of the Pythagorean Theorem. The textbook by Burger and Starbird (2010) comes with a kit that contains cutouts of four identical right triangles and one square. These five shapes can be arranged in multiple ways. One possibility is as a large square whose edges are the hypotenuses of four right triangles as in Figure 1. Another arrangement is as two concatenated squares as in Figure 2. The groups are asked to place their cut-outs, one set per group, on the table. For purposes of consistency in classroom conversation, the groups agree to denote the length of the long leg of each right triangle as **a,** the length of the short leg as **b**, and the length of the hypotenuse as **c.**

The assignment is to find two ways to arrange all five shapes to produce either one or two squares and to compute the area of each of these arrangements. After about 15 minutes, some groups will have found both configurations, perhaps aided by focused questions from the instructor. In calculating the areas, students will find that the area of the large single square, as in Figure 1, is c^2 and that the area of the concatenated squares, as in Figure 2, is $a^2 + b^2$.

Class Discussion

Finally, the instructor invites the students to explain how this exercise provides a justification of the Pythagorean Theorem. There are many alternative visual proofs of this theorem available in instructional materials. The benefits of this method are that the areas to be computed are for rectangular shapes and that algebraic manipulations are avoided, thus not frightening the students in the first activity. The two figures below are simple renditions of these geometric visualizations of the Pythagorean Theorem. Similar figures, in full color, may be found, for example, in Burger and Starbird (2010).

Figure 1: Geometric Visualization of the Pythagorean Theorem—1

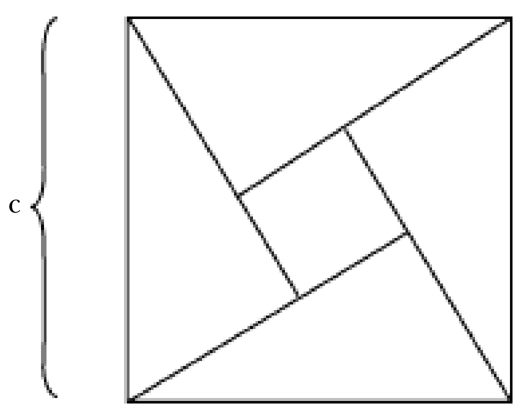
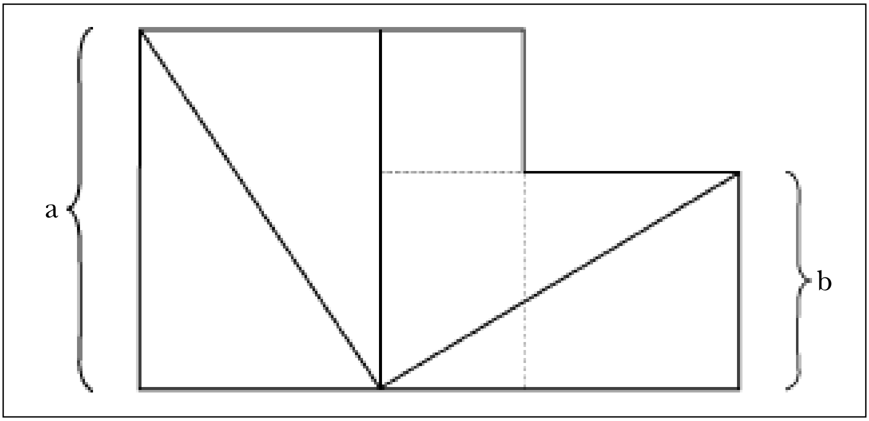


Figure 2: Geometric Visualization of the Pythagorean Theorem—2



During class discussion, the instructor should ask students to explain how they know that Figure 1 is actually a square. They should observe that the two angles at each corner are complementary, adding to 90º, and that the sides all have the same length. That Figure 2 is made up of two squares can be deduced from the first arrangement; the instructor should make sure that the class understands how to see this arrangement.

Writing Mathematics

To develop students' abilities to communicate mathematics accurately in writing, an assignment such as the following is a valuable exercise: Explain your proof of the Pythagorean Theorem, in writing, to a friend who may not clearly remember the theorem or be able to explain why it is true. (a) Give a clear statement of the Pythagorean Theorem and a few examples illustrating it. (b) Tell the reader that you are about to give a pictorial proof of why this theorem is true, and describe the set of cut-outs that you will use to do this. (c) Sketch the two arrangements of the cut-outs and explain how you can determine the area of each. (d) Explain how the Pythagorean Theorem emerges from this sketch.

Broader Context

After seeing that Pythagorean triples, such as (3, 4, 5) and (5, 12, 13), provide integer solutions of the equation $x^2 + y^2 = z^2$, the class will have an appreciation for the question of whether the corresponding equation, with the squares replaced by cubes, has integer solutions. The instructor can present the problem as a challenge exercise for homework: find a triple of integers (x, y, z) that satisfies $x^3 + y^3 = z^3$ and bring it to the next class meeting. This can be assigned to one or two groups, and other groups can be asked to find a triple satisfying $x^n + y^n = z^n$ for other values of n>2.

Of course, the next class meeting may be disappointing if the number of solutions is small. This results will lead-in to a discussion of the history behind Fermat's Last Theorem and its eventual solution in 1992. A great way to conclude this study is by viewing *The Proof,* a 1997 NOVA production.[4] This documentary tells the story of Fermat's Last Theorem in a way that can inspire and excite liberal arts students about mathematics.

Other Variations

Students can prove the Pythagorean theorem by using other geometric configurations of squares and triangles. This assignment can serve as a bonus problem for interested students or as an end-of-class project.

For honors students, communication is rarely a problem, but communicating mathematics, especially for liberal arts majors, offers a new twist. One way in which students' mathematical confidence grows is in the realization that a mathematical argument does not need to consist of a two-column proof: it can be a convincingly rigorous prose argument. Honors students love to discuss ideas, and so they naturally build their understanding of the mathematics by verbalizing it. Hearing students, especially those who considered themselves math-phobic at the beginning of the semester, heatedly and reasonably arguing about mathematics is wonderful.

Activity 2 is an adaptation to a liberal arts honors setting of materials by Shipman that appear in Chapter 2 of *Active Learning Materials for Critical Thinking in a First Course in Real Analysis*[5] and in "Determining Definitions for Comparing Cardinalities,"[6] in which the author explains in more depth the mathematical ideas and teaching strategies that she used in creating and implementing these materials. Activity 2 illustrates how one can structure a discussion for honors liberal arts students about whether it is possible to take something away from a set and still have a set of the same cardinality. The discussions integrate questions and ideas from two activities in the references by Shipman cited above: *Relabeling doors: A dilemma in comparing quantities,* and *More circles or more squares?* Further activities on counting from these references that work nicely in an honors course for liberal arts majors are *Handing out cards* and *An orange tiger.*

Activity 2: The Counting Numbers and the Even Counting Numbers

The Context

Instructors can present this exercise before any discussion of finite or infinite cardinalities. Traditionally, before instructors introduce infinite cardinalities, they show students that when comparing two finite sets, they can determine that the sets have the same size by constructing a one-to-one pairing between them rather than counting each set and comparing the two numbers. Presenting the following exercise before any discussion of one-to-one correspondences gives honors students the opportunity to explore their own notions about counting and come up with their own arguments and ideas before being exposed to the ways that mathematicians have, after decades of work, agreed to understand counting.

The Question

Does the set of counting numbers {1, 2, 3, . . . }, which we denote by N, *contain a greater quantity of elements than the set of even counting numbers,* 2N = *{2, 4, 6, . . . } ?* The students should offer their initial opinions so that they can discuss various points of view.

Initial Responses

The following are three common responses. (1) No, because both sets are infinite. (2) Yes, because N contains twice as many numbers as 2N. (3) It does not make sense to compare the sizes of infinite sets. The instructor will recognize a misconception about cardinality in each of these responses. The first correctly claims that N is not larger than 2N but incorrectly attributes this conclusion to the fact that both sets are infinite. The second response incorrectly assumes that a proper subset has a smaller cardinality than the original set. It also fails to recognize that the magnitudes of the numbers in a set has no influence on how many elements there are. The third response tries to avoid both dilemmas by claiming that comparing the sizes of two infinite sets is not reasonable. These three responses should be written on the board for the class to consider in the next step.

Group Discussion

The class may now discuss these options in groups of four. The assignment is for each person in the group to make a clear argument for or against each of the three responses and to present these arguments to the group. The students should base their arguments on clear mathematical reasons rather than on personal opinions or emotional inclinations. The goal is for each group to decide on one of the responses and, together, to formulate an argument to present to the class. The group should also formulate a clear argument against each of the other two responses. If a group remains sharply divided, then the members should craft two dissenting opinions. All arguments, once agreed upon by the group, should be expressed clearly in writing. This part of the exercise may take up to twenty minutes.

Presentation of Arguments

Once all the groups have produced their written statements, each group should write the argument for its chosen position on the board under the statement it supports and give a brief explanation. Even if one group's explanation seems to mirror the argument that has already been recorded, the group should still write it down since slight changes in wording may have dramatic effects on meaning. After all the groups have recorded their statements, the counter-arguments can be presented and recorded, perhaps in a different color, under the supporting arguments for each statement.

Reflection

After hearing all arguments for and against each of the three initial responses, the students should quietly reflect for a few minutes on what they have heard and possibly modify their positions. Instructors will also need some time to reflect on what the class has said in order to make a logical transition to the next stage of the exercise. Usually the groups articulate one or two strongly stated arguments for and against each of the first two responses. Some key opinions that the students will have presented take into account *what* the numbers in each set are rather than focusing exclusively on *how many* there are. This observation is the motivation for the next sequence of questions.

Further Questions

Instructors can now direct the class as a whole to the following questions: Do the names of the people on a committee affect how many there are? Do the heights of the houses in a neighborhood affect how many there are? Do the sets {3, 6, 9, . . . , 300} and {5, 10, 15, . . . , 500} have the same size? How can you explain your answers? Students will generally agree about the answers to the first two questions : "No. What the items are does not affect how many there are." The students should then recognize without much help that constructing a one-to-one pairing between two sets in the third question is an intuitive and natural way to show that one set contains exactly as many elements as the other. Armed with this observation and a clear acceptance that what the members of a set are does not affect their quantity, the students are ready to accept as reasonable and correct the following definition.

*Definition 1: Two nonempty collections have the **same cardinality** if there exists a one-to-one correspondence between them.*

Instructors should ask the class to give examples of collections or sets that have the same cardinality according to this definition. Most students will see an obvious pairing between N and 2N (pairing a natural number k with $2k$) and conclude correctly that the sets have the same cardinality. It is instructive here to offer the counter-argument that 2N can be mapped into N by sending n to n. Does this contradict the definition? This discussion provides a good opportunity to emphasize the importance of carefully reading mathematical statements.

Checking Students' Confidence

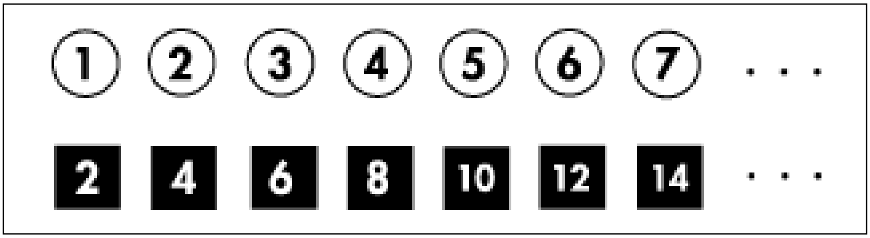
The following true/false question tests students' acceptance of the perhaps unintuitive outcomes of Definition 1: *True or False? After all the work that mathematicians have put into comparing infinite cardinalities, it is still true that there is a greater quantity of counting numbers than even counting numbers.* Even after working through Activity 2 up to this point, some students may admit that they still secretly believe that there is a greater quantity of counting numbers than even counting numbers, despite openly acknowledging that the two sets have the same size by Definition 1. The activity *More Circles or More Squares?* in *Determining Definitions for Comparing Cardinalities* (Shipman, 2012) is designed to help students out of this uncomfortable position. The investigation that follows is a simplified version of this activity for liberal arts honors students. It will help them to dispel any lingering belief that the counting numbers should be more numerous than the even counting numbers.

First, the class is divided into two groups. For the purpose of the exercise, Group 1 takes the position that the counting numbers are more numerous than the even counting numbers, and Group 2 takes the position that these two sets of numbers have the same size.

The students are asked to imagine that we have infinitely many solid circles and infinitely many solid squares (made of cardboard, for example). Each circle is white on one side and black on the other side. On the white side, the circles are numbered in black by the counting numbers. On the black side of each circle, the number $2k$ is written in white, where k is the number that appears on the opposite side. (For example, the circle with the number 5 written on its white side has the number 10 written on its black side.) The squares are colored and numbered in the same way.

Now imagine that the circles and squares are lined up on an infinitely long piece of glass. Figure 1 shows the view from the front of the window, exhibiting the white sides of the circles and the black sides of the squares.

Figure 3: Front View (white sides of circles and black sides of squares)



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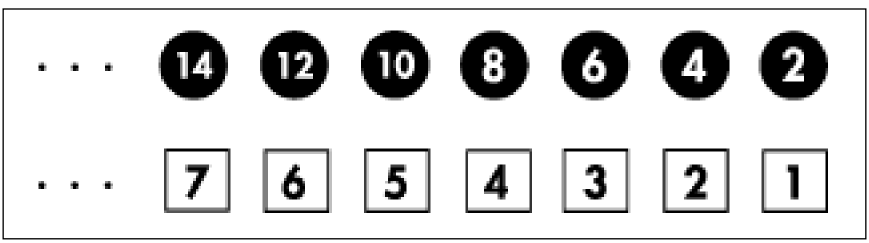
The students now think quietly about the following question before answering it:

> *Question: Judging by the position that your group has been asked to take, and looking at the numbers in figure, which are more numerous: the circles, the squares, or neither?*

Group 1 will find the circles to be more numerous while Group 2 will conclude that the two sets have the same size.

The class then views the display from the back side and answers the question again:

Figure 4: Back View (black sides of circles and white sides of squares)



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From this perspective, Group 1 now finds the squares to be more numerous while Group 2 finds again that the two sets have the same size.

Conclusion

The class will see that the position of Group 1 (that the counting numbers are more numerous than the even counting numbers) gives contradictory answers, depending on which side of the window one is viewing, while the position of Group 2 (that the two sets have the same size) gives the same answer from both perspectives. This situation provides convincing grounds for liberal arts students to abandon the deceiving perception that the counting numbers are more numerous than even counting numbers and to accept Definition 1 as the "right" way to compare cardinalities.

A final phase of Activity 2 is to have the students decide whether comparing the sizes of infinite sets is an interesting question or whether it even makes sense to talk about it. Additional questions may be considered in a similar manner: Are some infinite sets larger than others? If more elements are added to an infinite set, must the set become larger? What do "larger" and "smaller" mean in terms of infinite sets?

Through discussions like these, instructors can lead students to formulate reasonable and self-consistent definitions of mathematical concepts. They will recognize that they have no alternative but to accept the often counterintuitive outcomes: there are exactly as many even integers as integers, and there are exactly as many numbers between 0 and 1 as there are on the whole infinite real line. Someone encountering such statements for the first time may think that mathematics is simply outlandish, but these honors students, from any major, can now offer solid explanations for why these outcomes, strange as they may seem, are indeed properties of infinite sets.

Two essays, "Cantor's New Look at the Infinite" and "To Infinity and Beyond" from the collection of essays in *To Infinity and Beyond*,[7] offer a historical perspective on the development of the mathematical concept of cardinality. In reading them, students are relieved to learn that the same questions that gave them headaches in class gave the most brilliant mathematicians at least as hard a time and caused at least as many arguments among them. Even Leopold Kronecker, Georg Cantor's mentor, refused to accept Cantor's rigorous and ingenuous formulation of cardinality. For more on the intriguing topic of infinity, Jorgensen and Shipman's *Limits of Infinite Processes for Liberal Arts Majors: Two Classic Examples*[8] offers engaging classroom activities that recast complex ideas on limits into settings that are tangible and visual, opening up new ways of mathematical thinking for the honors liberal arts student.

In Honors Liberal Arts Mathematics, students also learn to write mathematics with precision and clarity so that someone who does not already know the mathematics can read their work and understand the question, the method of solution, and the conclusion. Giving writing assignments to groups of two or three students allows them to check each other's writing for completeness and clarity. A writing assignment is usually based on a problem that has been discussed at length in class; thus the students have already explained their solutions verbally. The paper should include the following components.

Statement of Purpose

The introduction should state the purpose of the paper, which could be to present a mathematical problem, explain its solution, or verify that the solution works, and give examples to illustrate the results.

Statement of the Problem

This section should include, as appropriate, clearly labeled diagrams, definitions of concepts used in stating the problem, and a few illustrative examples.

Definitions

Before solving equations or analyzing a table or diagram, writers must tell their readers what the equations mean and what the entries and notations in the table or diagram are. This section should define all variables, with units if appropriate, and state the meaning of any equations, tables, or diagrams that will be considered.

Explanation of the Solution

The writers must take the readers carefully through each step of the solution because they must assume that the readers do not already know how to solve the problem.

Statement of the Result

After guiding readers through the solution and arriving at the final result, the writers should clearly state what has just been shown. This section will confirm that the arguments presented have indeed answered the problem posed at the beginning.

Verification of the Solution

Unless the problem is to prove a statement, checking the solution in some way is usually possible. This may be as simple as plugging in the answer to see that it works or it may involve verifying a strategy for winning a game by testing it on examples that cover a variety of possible cases.

In writing projects such as these, instructors have the opportunity to help the students, many of whom are English majors, to write precisely. What the students write should express what they mean, but often it does not. To help with this problem, one may assign shorter writing exercises in which students work in small groups to formulate in writing, without the help of the textbook or notes, a definition or mathematical result that has either been discussed previously in class or that they have seen in their previous mathematics education.

The task may be writing down what it means for a number to be prime or explaining clearly in writing how to put a fraction into lowest terms. Other challenges are to give a good definition of a function and to state in writing, without equations, what a circle is. Students can experiment with writing a clear algorithm to find the least common multiple or the greatest common divisor of two positive integers.

After each group has produced a written statement, the students should write them on the board. Each statement should be read carefully and taken at face value for exactly what it says, without interpreting it according to what the writer meant to say or according to what the readers believe that the writers meant. When a statement does not correctly express what is being defined, the instructor should present examples that satisfy what is written but do not correspond with what is intended. An example follows Statement A: To find the greatest common divisor of two positive integers, multiply the factors that go into both numbers. This claim means, then, that to find the greatest common divisor of 12 and 18, one must multiply 2, 3, and 6 to obtain 36. The students will readily agree that this statement is not correct but that this process is what the statement says to do. They might then modify this to Statement B: To find the greatest common divisor of two positive integers, multiply the prime factors that go into both integers. Now, to find the greatest common divisor of 24 and 36, Statement B instructs students to multiply 2 and 3 to obtain 6. The students will agree that this process is not correct either, and the discussion continues until the students write a correct statement.

After weeks of working together in this way, students will come to know each other well and will find peers with common interests and goals. The class often culminates in formal small group presentations on topics chosen by the groups. Some topics on which students have become the house experts include chaos, interconnections between mathematics and music, deciphering bar-codes, and the role of game theory in jury selection and medical decision-making.

Honors Calculus

The second major component of the lower-division honors experience in mathematics is Honors Calculus. A sequence of Honors Calculus courses is a wonderful opportunity to build a mathematical learning community among students. Many honors freshmen entering a college or university may not yet be sure what their career goals or major will be but will want to take enriched courses such as Honors Calculus. Indeed, this course may be for many honors students, of any potential major, a first experience in seeing, discovering, and understanding the richness of ideas that mathematics has to offer.

UT Arlington offers a year-long sequence, Calculus I and Calculus II, as honors courses. Roughly the same group of students takes both semesters of the course, so they receive an academic year of exposure to the same instructor and the same peers. Many of the students share common schedules in their other courses as well. Thus, the learning community fostered in their calculus course spills over and supports interactions in their other courses.

In a traditional calculus class, students spend much of the time understanding and practicing techniques for the computation of limits, derivatives, and integrals. As all mathematics instructors know, students can quite easily mistake the forest for the trees. In an honors course, instructors have the luxury of expecting and requiring the students to reflect upon and understand how the topics fit into their cumulative mathematical knowledge. All four primary expectations of an honors mathematics course can be developed in the context of an Honors Calculus sequence: ownership, communication, mathematical maturity, and broader context. While one instructor may choose a reform calculus text,[9] another may use a more standard text.[10] Shipman's "A Comparative Study of Definitions on Limit and Continuity"[11] is an additional resource well-suited for honors calculus; it takes a penetrating look at definitions on limit and continuity in a way that will prod students to think carefully about how every part of a definition is constructed.

The structure of the course rather than the textbook, however, provides the enrichment expected in an honors class. Each week of Honors Calculus consists of three hours of lecture and two hours of lab. Instead of conducting recitation in the traditional way by simply going over homework problems, instructors base each lab session on a worksheet of problems that they construct; these problems are much more challenging and far-reaching than those assigned from the textbook, and numerous resources for engaging projects, problems, and lab worksheets on topics in calculus are available.[12] In the labs, the students work in small, self-selected groups to find satisfactory solutions to the problems. The instructors serve as facilitators, posing questions that help the students gain a deep understanding of the problems but rarely answering questions. This approach serves many purposes. First, the students develop working relationships with the other students in class, relationships that will carry through to other courses that they will take together. Second, the students develop a sense of mathematical confidence. Because they become accustomed to instructors responding to all of their questions with more questions, they develop an ability to know when they are on the right track and begin to answer their own leading questions. This lab structure is modeled in part after the format utilized by the Emerging Scholars Program at the University of Texas at Austin and the MathExcel Program at the University of Nebraska-Lincoln. Epperson's seminal and widely disseminated set of worksheets[13] for these programs served as a catalyst for worksheets developed for this setting. To emphasize accountability, all students must submit their solutions to the lab worksheets the following week.

In one type of problem considered in the lab sessions, the students play the role of the teacher in that they need to create problems or find examples fitting specifications to illustrate key ideas. By building their own examples rather than simply applying theorems or results derived in class, the honors students develop a more complete understanding of the concepts and an ownership of those ideas. The following example is typical of the problems found in the reform calculus text or the worksheets referred to above.

Example 1: A Sum Rule for Non-Existent Limits?

The Problem

Do there exist two functions f(x) and g(x) and a constant c such that $\lim_{x\to c} f(x)$ *does not exist,* $\lim_{x\to c} g(x)$ *does not exist, but* $\lim_{x\to c} (f(x) + g(x))$ *does exist? Either find an example, or prove that no such example exists.*

To solve this problem, students must know more than how to compute a limit: the students must put their knowledge of functions into the context of limits to try to create a counterexample to a common mistaken theorem that calculus students often try to apply. First, they must think about how to build a function for which the limit does not exist at some value $x = c$. Then they need to consider how they can fix the bad behavior by adding another function. This problem can be adapted or expanded by considering a different limit rule, e.g., the limit of the product of functions or the limit of the composition of functions, and also by changing the limit behavior of the constituent functions. There are infinitely many solutions to this problem, but one simple solution is to let $f(x) = \frac{1}{x}$ and $g(x) = -\frac{1}{x}$ and consider their behavior at $x = 0$.

A second type of problem emphasized on the lab worksheets asks students to explain concepts in their own words: *Give an explanation of the Mean Value Theorem that a pre-calculus student could understand. Your explanation should be both verbal and pictorial.* These may also be interpretation problems explaining what a derivative means. The reform calculus textbook *Calculus: Single Variable* by Hughes-Hallett et al. offers many problems of this kind. One such example taken from the Hughes-Hallett text is the following:

Example 2: A Derivative in Practical Terms

The Problem

A company's revenue from computer sales, R, measured in thousands of dollars, is a function of advertising expenditure, a, also measured in thousands of dollars. Suppose $R = f(a)$. *Explain what the statement* $f'(301) = 2$ *means in practical terms.*

It is important, especially on these interpretation problems, to require the students to really answer the question. Students will often solve the previous problem by saying that $f'(301) = 2$ means the derivative of f at 301 is 2. The instructor's job is to draw out the answer by asking a sequence of scaffolding questions that guide the groups to fully consider the problem. For example, what are the units of the number 301? What are the units of the number 2? What does f measure? Do you have any information about the value of $f(301)$? Do you need it? How would the computer company use information about f'? If the company is already spending $301,000 on advertising, would it be wise for the company to increase its advertising expenditures? If, $f'(301) = 0.3$, would your answer to the previous question change?

A complete answer to this problem should include the following information: $f'(301) = 2$ means that if the company is already spending $301,000 on advertising and it spends a little bit more on advertising, it would expect its revenue to increase by approximately twice the amount of increase in advertising expenditure. For instance, if it spends $301,100 on advertising, it would expect its revenue to go up by about $200, so it would make back the extra $100 it spent on advertising, plus $100 more.

These problems seek to make connections between the computational and conceptual ideas of calculus and hone the honors students' abilities to communicate and to justify their perceptions. Instructors should expect students to periodically present their ideas and solutions to problems to the rest of the class, further reinforcing the need to communicate mathematics. To encourage the students to keep up with the regular homework assignments, one lab each week starts with ten to twenty minutes of presentations of homework problems by students. Instructors can select three homework problems assigned the previous week. The students do not know ahead of time which problems will be presented. Three randomly selected students present their homework problems. During the semester, each student will have the opportunity to present.

The following grading scheme has worked well. If students are not at lab that day, they earn zero points for the presentation. If students are at lab but do not feel ready or willing to present the requested problem, they earn two points for attendance. Five points are awarded if a student presents a solution. The atmosphere during the presentations should not be stressful or pressured. They are opportunities for the students to practice communicating mathematics and refining their solutions. Again, emphasizing that mathematics needs to be communicated and that students who present their work to others often find mistakes is important. This practice mirrors the way professional mathematicians work and make discoveries.

A major component of the Honors Calculus I and Calculus II courses is an extensive collaborative project culminating in a professionally written report. The students work in small groups of four, and most of their work on this project is done outside of class. The groups are chosen by the instructor to ensure that each group contains students with different abilities and that the students' schedules align for at least two available working hours each week. All the groups work on the same project. The students have a month and a half to complete the project, and the final product must demonstrate high mathematical quality and be well written.

Crucial to the success of these group projects is constructing a timeline for completion. A minimal timeline should include a date for an initial meeting with the instructor to discuss the group's preliminary ideas, the date by which the first draft is due to be submitted and reviewed, and the final submission date. Each group submits a single final paper, which should be mathematically typeset and include appropriate diagrams. Students should be encouraged to address their paper to a reader who is superior to them in position, a supervisor for instance, but equal to them in knowledge of calculus. In addition, their paper should be rich in context, explanation, and prose. Often students expect that a mathematical paper should look like the solution to a homework problem with nothing but numbers and symbols. Presenting the students with a model project write-up from a previous semester or a sample of exemplary mathematical writing at the college level is helpful.

Many sources offer rich calculus project problems.[14] A recent Calculus I group project, for example, was based on designing a suspension bridge to satisfy prescribed dimensions. The students needed to determine the length of a catenary supporting the bridge, using only their knowledge of Calculus I. They had not yet encountered the arc length formula, and through the project, the students developed the formula. Another Calculus I project involved measuring the volume of wine in a barrel with a bung rod after finding the optimal barrel dimensions.[15] A recent Calculus II project had the groups finding the generating function of the Fibonacci sequence via Taylor series, and another revolved around employing power series and clever use of trigonometric identities to find more efficient ways to compute many digits of π. Such group projects reinforce the cooperative atmosphere of the classroom, requiring the students to work together extensively on their own time. The final papers the groups produce are often creative and entertaining to read, which is always a delight for the instructors.

Anecdotal evidence of the successful creation of an atmosphere of enjoyable community learning occurred during the final exam period for the Honors Calculus I class in Fall 2006. Lying in wait to celebrate their final exam by blowing bubbles, the students surprised their professor by decorating a room with streamers and confetti and providing a buffet of home-baked cupcakes. The students truly feel that the class is their own and that their peers are their collaborators, defining a true honors experience in mathematics that will likely remain a highlight for the students for the rest of their undergraduate careers.

Bibliography

Burger, Edward B., and Michael P. Starbird. *The Heart of Mathematics: An Invitation to Effective Thinking*. 3rd ed. Hoboken, NJ: Wiley & Sons, 2010.

Charles A. Dana Center. University of Texas at Austin. *Supporting and Strengthening Standards-based Mathematics Teacher Preparation: Guidelines for Mathematics and Mathematics Education Faculty*. J. Epperson, D. Pace, & K. Childs, eds. Austin: University of Texas at Austin, 2004.

Diefenderfer, Caren L., and Roger B. Nelsen, eds. *The Calculus Collection: A Resource for AP and Beyond.* The Mathematical Association of America, 2010.

Digby, Joan. *Smart Choices: Honors Programs and Colleges.* Princeton, NJ: Peterson's, 2005.

Epperson, James. "Calculus I Worksheets." Treisman Workshop Resources Worksheet Archive. Available online at <http://math.sfsu.edu/hsu/workshops/resources.html>.

—-. "Calculus II Worksheets." Treisman Workshop Resources Worksheet Archive. Available online at <http://math.sfsu.edu/hsu/workshops/resources.html>.

Farmer, David W., and Theodore B. Stanford. *Knots and Surfaces: A Guide to Discovering Mathematics.* Providence: American Mathematical Society, 1996.

Hughes-Hallett, Deborah, Andrew M. Gleason, William G. McCallum, David O. Lomen, and David Lovelock. *Calculus: Single Variable.* 5th ed. John Wiley and Sons, 2008.

Jorgensen, Theresa, and Barbara A. Shipman. "Limits of Infinite Processes for Liberal Arts Majors: Two Classic Examples." *PRIMUS: Problems, Resources, and Issues in Undergraduate Mathematics Studies* 22, no. 6 (2012): 482–499.

Maor, Eli. *To Infinity and Beyond: A Cultural History of the Infinite.* Princeton, NJ: Princeton University Press, 1987.

National Collegiate Honors Council website of honors program recommendations: <http://www.nchchonors.org/basichonorsprogramcharacteristics.shtml>. Accessed 10 April 2012.

NOVA: The Proof. Directed by Simon Singh, produced by Paula Apsell. WGBH Boston, 1997, DVD/VHS.

Shipman, Barbara A. *Active Learning Materials for Critical Thinking in a First Course in Real Analysis.* Published online at <http://www.uta.edu/faculty/shipman/analysis>. 2009.

—-. "A Comparative Study of Definitions on Limit and Continuity." *PRIMUS: Problems, Resources, and Issues in Undergraduate Mathematics Studies,* forthcoming.

—-. "Determining Definitions for Comparing Cardinalities." *PRIMUS: Problems, Resources, and Issues in Undergraduate Mathematics Studies* 22, no. 3 (2012): 239–254.

Strauss, Monty J., Gerald L. Bradley, and Karl J. Smith. *Calculus.* Boston: Pearson Custom Pub., 2006.

Sumners, De Witt. "Lifting the Curtain: Using Topology to Probe the Hidden Action of Enzymes," *Notices of the American Mathematical Society* 42, no. 5 (May 1995): 528–537.

Notes

[1]<http://www.nchchonors.org/faculty-directors/basic-characteristics-of-a-fully-developed-honors-college/> Accessed 10 April 2012.

[2]Edward B. Burger and Michael P. Starbird, *The Heart of Mathematics: An Invitation to Effective Thinking*, 3rd ed. (Everyville, CA: Key College Publishing, 2005); Eli Maor, *To Infinity and Beyond* (Princeton University Press, 1987); David W. Farmer and Theodore B. Stanford, *Knots and Surfaces: A Guide to Discovering Mathematic* (Providence: American Mathematical Society, 1996).

[3]Burger, Edward B. and Michael P. Starbird, *The Heart of Mathematics: An Invitation to Effective Thinking*, 3rd ed. (Hoboken, NJ: Wiley & Sons, 2010).

[4]*NOVA: The Proof.* Directed by Simon Singh, produced by Paula Apsell. WGBH Boston, 1997, DVD/VHS.

[5]Barbara A. Shipman, *Active Learning Materials for Critical Thinking in a First Course in Real Analysis,* Published online at <http://www.uta.edu/faculty/shipman/analysis>. 2009.

[6]Barbara A. Shipman, "Determining Definitions for Comparing Cardinalities," *PRIMUS: Problems, Resources, and Issues in Undergraduate Mathematics Studies* 22, no. 3: 239–254, 2012.

[7]Eli Maor, *To Infinity and Beyond,* (Princeton University Press, 1987).

[8]Theresa Jorgensen and Barbara A. Shipman, "Limits of Infinite Processes for Liberal Arts Majors: Two Classic Examples." *PRIMUS: Problems, Resources, and Issues in Undergraduate Mathematics Studies* 22, no. 6 (2012): 482–499.

[9]Deborah Hughes-Hallett, Andrew M. Gleason, William G. McCallum, David O. Lomen, and David Lovelock, *Calculus: Single Variable.* 5th ed. (John Wiley and Sons, 2008).

[10]Monty J. Strauss, Gerald L. Bradley, and Karl J. Smith. *Calculus.* (Boston: Pearson Custom, 2006).

[11]Barbara A. Shipman, "A Comparative Study of Definitions on Limit and Continuity." *PRIMUS: Problems, Resources, and Issues in Undergraduate Mathematics Studies,* forthcoming.

[12]For a repository of projects and ideas, see Caren L. Diefenderfer and Roger B. Nelsen, eds. *The Calculus Collection: A Resource for AP and Beyond* (The Mathematical Association of America, 2010). For a seminal

set of worksheets, see James Epperson, "Calculus I Worksheets" and "Calculus II Worksheets," from Treisman Workshop Resources Worksheet Archive. Available online at <http://math.sfsu.edu/hsu/workshops/resources.html>.

[13]James Epperson, "Calculus I Worksheets" and "Calculus II Worksheets" from Treisman Workshop Resources Worksheet Archive. Available online at <http://math.sfsu.edu/hsu/workshops/resources.html>.

[14]For some sources of good problems, see Hughes-Hallett et al., *Calculus: Single Variable; Supporting and Strengthening Standards-based Mathematics Teacher Preparation: Guidelines for Mathematics and Mathematics Education Faculty*. J. Epperson, D. Pace, & K. Childs, eds. (Austin: University of Texas at Austin, Charles A. Dana Center, 2004); Caren L. Diefenderfer and Roger B. Nelsen, eds., *The Calculus Collection: A Resource for AP and Beyond* (The Mathematical Association of America, 2010).

[15]Monty J. Strauss, Gerald L. Bradley, and Karl J. Smith. *Calculus* (Boston: Pearson Custom Publishing, 2006).

Chapter 10

STATISTICS IN HONORS: TEACHING STUDENTS TO SEPARATE TRUTH FROM "DAMNED LIES"

Lisa W. Kay

Introduction

H. G. Wells reportedly once said, "Statistical thinking will one day be as necessary for efficient citizenship as the ability to read and write."[1] People need to have a basic understanding of fundamental statistical concepts because they are constantly bombarded with quantitative information in the media. In many cases everyday activities like reading the newspaper require statistical thinking if people are to process the given information intelligently. Understanding the risks associated with taking a new medication, for example, requires a rudimentary knowledge of probability.

A few years ago, the author proposed a statistics course as a junior-level elective for the Eastern Kentucky University (EKU) Honors Program because statistical thinking is particularly crucial for honors students. They need to be able to use quantitative information to support or refute arguments, and honors students often need statistics in their theses. At times senior thesis presentations contain statistical atrocities: the use of voluntary response samples, which produce biased results; the inclusion of flawed graphical depictions of data; and the misuse of statistical terminology. A statistics course in honors offered at the junior level should reduce the number of such errors in senior work.

Design of the Course

As an alumna of the program, the author knew that she wanted to propose a course that features some of the program's hallmarks: an interdisciplinary theme, team teaching, and panel presentations. In addition, the course should include the recommended characteristics found in the Guidelines for Assessment and Instruction in Statistics Education (GAISE) <http://www.amstat.org/education/gaise/>:

- Emphasize statistical literacy and develop statistical thinking;
- Use real data;
- Stress conceptual understanding rather than mere knowledge of procedures;
- Foster active learning in the classroom;
- Use technology for developing conceptual understanding and analyzing data;
- Use assessments to improve and evaluate student learning.

The field of statistics is inherently interdisciplinary because real data always exist in the context of some other field. Many different fields typically represented on a college campus could be appropriately paired with statistics in an interdisciplinary honors course. At the beginning of the course development process, the author contacted a professor from the Department of Government, and the two agreed to design the course together. They wanted to incorporate some of the elements of the Chance course that originated at Dartmouth College and to emphasize the prominent role that statistics play in people's lives: "Governed by Chance" seemed like an appropriate title for the course.[2]

One of the first decisions the teachers attacked when designing the course was that of textbook selection. The author knew that David S. Moore had tagged his *Statistics: Concepts and Controversies* as a liberal arts approach to introductory statistics, so it was chosen as the primary statistics text.[3] Moore's book focuses on concepts, requires little mathematical background to read, emphasizes the need for an understanding of statistics in everyday life, and includes some specific examples of the use of statistics in government. Having a textbook that emphasizes concepts over computations is essential in an honors statistics class in which the primary audience consists of non-majors. The instructors also wanted a text that would promote discussion about the use and abuse of statistics in contemporary situations. They examined *Tainted Truth: The Manipulation of Fact in America*[4] and *It Ain't Necessarily So: How Media Make and Unmake the Scientific Picture of Reality*[5] but ultimately settled on a more recent book, Joel Best's *More Damned Lies and Statistics: How Numbers Confuse Public Issues.*[6] Best illuminates many common misperceptions, and he highlights the role that the media play in promulgating such misperceptions. Since the honors students at EKU have book scholarships, the instructors added a book that is used sometimes in Chance classes: Edward Tufte's *The Visual Display of Quantitative Information.*[7] Tufte provides views on the ways in which graphical displays can be deceptive, and he gives readers advice regarding the creation of aesthetically pleasing graphics.

While the class covered several chapters of Tufte's book the first time the course was offered in the fall of 2005, the instructors decided to use only one chapter of the book in the second iteration of the course in 2007. Although the material is interesting and is something not typically seen in a standard statistics course, it did not contribute much to the government/statistics theme. The teachers continued to use the Moore and Best books (Moore had released a new edition and added co-author Notz) and added *Quantitative Methods in Practice: Readings from PS* in order to inject more government content in the course.[8] (The 2007 syllabus is available in the Appendix.)

The texts introduced statistical topics like data production, describing data with graphs and with numerical summaries, relationships among variables, probability, and inference. By the end of the course, students could collect data in proper ways and recognize flawed data collection methods; create accurate, uncluttered graphs to describe data; compute basic numerical summaries; understand that association does not imply causation; have a sense of the meaning of randomness; calculate and interpret simple probabilities; and draw conclusions about a population based on information contained in a sample. One goal of any statistics course is helping the students to develop a healthy level of skepticism and a feel for what is reasonable. That students can read an article that contains statistical information and then ask the appropriate questions to establish the legitimacy of what is presented is important.

To promote the development of these skills, the instructors incorporated one of the aspects of Chance classes: inviting guest speakers. Early in the fall semester of 2005, a librarian spoke to the class about sources of statistical information and how to determine whether a source is reliable. The Dean of the College of Arts and Sciences at the time was also Professor of Geography, and he gave a presentation to the class about the inclusion of statistical information in maps, including a discussion of the famous map of Napoleon's March by Charles Joseph Minard.[9] The dean's lecture dovetailed nicely with the course material from Tufte's book. Also in the fall of 2005, Dr. Boyd Haley,[10] a controversial figure and Professor of Chemistry from the University of Kentucky, spoke to the class about his research that suggests a link between mercury and certain disorders such as autism. This presentation gave the students the opportunity to make judgments about quantitative information that conflicts with standard evidence reported by government entities. In the 2007 version of the course, Trey Grayson, Kentucky's Secretary of State, addressed students regarding the use of statistics in government.[11] Although efforts to spend more time on government examples resulted in the inclusion of fewer speakers in 2007, the presentations by guest speakers seemed to be a positive facet of the course, exposing students to a variety of viewpoints and reminding them of the responsible citizen's need for quantitative literacy.

The inclusion of active learning and real-life examples in an honors statistics course keeps the students engaged, provides students with greater insight into challenging concepts, and emphasizes the need for quantitative literacy. For both iterations of Governed by Chance, the instructors devoted some time to hands-on activities. These activities included "Random Rectangles";[12] creation of a human histogram to describe the height distribution in the class; and a regression activity involving Slinky® toys, baskets, and candy. The instructors also regularly brought recent articles to class to demonstrate the relevance of statistical knowledge in today's society and particularly in the field of political science. Activities and discussions surrounding timely topics contribute to a lively atmosphere in which the exchange of ideas is not only welcome but expected.

Another important aspect of any statistics course is the utilization of technology. The teachers employed Minitab® <http://www.minitab.com/> and, to a lesser extent, Excel. (Excel is not ideal for statistical analysis, but it may be the only package with statistical features to which some alumni will have access in their future jobs.) There are other statistical software packages available for use in the classroom, such as SPSS® <http://www.spss.com/>, JMP® <http://www.jmp.com/>, and the freeware package R <http://www.r-project.org/>. The instructors also expected all students to have scientific calculators, preferably with two-variable statistical functions. For an honors statistics class comprised of non-majors, a menu-driven package like Minitab would work better than a command-driven package like R.

Challenges and Opportunities for Improvement

When Governed by Chance was first offered as an honors course, it was cross-listed as both a statistics course (with the STA prefix) and a political science course (with the POL prefix). No one enrolled in the course with the STA prefix, but many students signed up for the POL version—they comprised the majority of the class. In fact, only a few honors students were enrolled. The political science students had little interest in statistics and, not surprisingly, wanted more government content. The instructors decided not to cross-list the course when it was offered a second time. The honors students had a better understanding of the interdisciplinary nature of the class at the beginning of the semester and, hence, more realistic expectations about what they would encounter. While the author would not rule out cross-listing the course in the future, she thinks it would be more successful if the department(s) in question used a new course number and a course description that captures the spirit of the course rather than a generic seminar course description.

Dealing with the variability in the students' statistical backgrounds was also challenging. Many students enrolled in Governed by Chance had taken no more than the most basic mathematics course offered at EKU while some students had taken or were enrolled concurrently in introductory statistics courses. Some students felt that the material was challenging, whereas others were bored when the instructors introduced concepts they had already seen. This variation is not surprising, but it is not an issue that an instructor typically faces while teaching an introductory statistics course. Inclusion of more writing and interdisciplinary discussions in the course might help to bridge this gap that exists between mathematically inclined students and students whose majors do not require quantitative courses.

Some of the students who took Governed by Chance made some negative comments on the teaching evaluation forms regarding the team teaching. Evidently, they were uncomfortable whenever the instructors expressed differing views or used different terminology. This team-teaching issue is not unique to this particular course; naturally, an educator from the mathematical sciences and one from the social sciences would have different perspectives and use different jargon. While it is acceptable, and maybe even desirable, for the students to be uncomfortable at times, students should, nevertheless, emerge from their undergraduate years with the understanding that two opposing viewpoints do not necessarily have to be labeled as "right" and "wrong." Perhaps addressing this issue at the beginning of the semester would encourage students to view the instructors' differing perspectives in a positive light.

The instructors required group projects and presentations in both iterations of Governed by Chance. Of course, they encountered some of the typical challenges that come with assigning group work: some groups have inequities in workload among group members; it can be a race against time to complete the projects by the end of the semester;

and the instructors must spend a significant amount of time providing the groups with guidance. One surprising element of the group projects was how much guidance some of the students wanted, especially since they were free to choose any topic that combined statistics and government/political science. Having that much creative freedom was disconcerting to some students; they wanted the teachers to select their topics for them. Reminding the students that this project could contribute to preparing them for other honors courses and senior theses might elicit more positive responses.

EKU requires that all courses approved for General Education be assessed at least once every two years. Information about EKU's assessment process and rubrics can be found at <http://www.gened.eku.edu/course-assessment-information>. The instructors assessed the course in the fall of 2007, using several questions on the final exam. The results indicated that the students were prepared to approach problems or questions with logical strategies and to perform necessary mathematical operations. The assessment results also suggested that the instructors needed to adjust their syllabus to spend more time on the interpretation of inferential procedures.

The Future

The author would like to find ways to inject more government content into the course without sacrificing the statistical content or the group work. She thinks that one way to accomplish this goal would be to replace some of the examples used in class with examples that are based upon government or political science data sets. In future iterations of the course, the instructor would also like to find fresh activities and examples that will hold the attention of students who have some prior statistical knowledge.

While not willing to give up the interactive team teaching or the group projects, the instructors would, however, like to identify avenues for helping students to understand the justifications behind and benefits of these processes. Recently, the author worked with a professor from Family and Consumer Sciences to develop another course. The author hopes to offer the class as a seminar in which the instructors will teach students how to use statistics for advocacy in the community, and the honors program has acquired service-learning status for the course. The author is considering using a book from the *Workshop Statistics* series as one of the texts.[13]

Resources

An abundance of resources can aid faculty in the development of courses that promote statistical thinking. As noted previously, all courses with statistical content should adhere to the GAISE guidelines. The full GAISE College Report can be found at <http://www.amstat.org/education/gaise/>, and it provides specific suggestions about how to incorporate the guidelines in college courses.

The American Statistical Association enumerates resources for instructors of undergraduate statistics courses at <http://www.amstat.org/education/index.cfm?fuseaction=undergrad>. The Mathematical Association of America Special Interest Group on Statistics Education also presents resources for statistics teachers at <http://www07.homepage.villanova.edu/michael.posner/sigmaastated/>. Both the Joint Statistical Meetings and the Joint Mathematics Meetings provide opportunities for statistics instructors to exchange ideas.

Information about Chance classes, including sample syllabi and lectures, can be found at <http://www.dartmouth.edu/~chance/>. The Science Education for New Civic Engagements and Responsibilities (SENCER) provides detailed information on several model courses that involve statistics at <http://www.sencer.net/Resources/models.cfm>. SENCER also offers Summer Institutes for teachers, administrators, and students. (See Chapter 4 in this monograph.) The website for the Consortium for the Advancement of Undergraduate Statistics Education (CAUSE) <http://www.causeweb.org/> has a vast array of resources for statistics educators. This site also gives information about the United States Conference on Teaching Statistics (USCOTS), the Electronic Conference On Teaching Statistics (eCOTS), and upcoming webinars. Held in odd-numbered years, USCOTS is a fantastic conference for statistics educators, and eCOTS is a new virtual conference that will occur during even-numbered years. The Assessment Resource Tools for Improving Statistical Thinking (ARTIST) site at <https://apps3.cehd.umn.edu/artist/> provides instructors with assessment resources for introductory statistics courses.

Conclusion

Honors statistics educators want to produce honors graduates who are quantitatively literate consumers and producers of data. Honors students need statistical skills for completion of coursework and theses as well as for responsible citizenship. The honors program can provide students with some of these skills through elective courses that offer a more thought-provoking survey of important statistical issues than standard introductory courses in statistics.

Bibliography

Assessment Resource Tools for Improving Statistical Thinking. Available online at <https://apps3.cehd.umn.edu/artist/>.

Best, Joel. *More Damned Lies and Statistics How Numbers Confuse Public Issues.* Berkeley: University of California Press, 2004.

Center for Statistics Education. American Statistical Association. Available online at <http://www.amstat.org/education/index.cfm?fuseaction=undergrad>.

The Chance Project. Mathematics Department. Dartmouth College. Available online at <http://www.dartmouth.edu/~chance/>.

Consortium for the Advancement of Undergraduate Statistics Education. Available online at <http://www.causeweb.org/>.

Course Assessment Information. Eastern Kentucky University. General Education Faculty Information. Available online at <http://www.gened.eku.edu/course-assessment-information>.

Crossen, Cynthia. *Tainted Truth: The Manipulation of Fact in America.* New York: Touchstone, 1996.

Gigerenzer, Gerd. *Rationality for Mortals: How People Cope with Uncertainty.* New York: Oxford University Press, 2008.

Grayson, Trey. Kentucky Secretary of State Website. Available online at <http://apps.sos.ky.gov/secdesk/sosinfo/default.aspx?id=74>.

Guidelines for Assessment and Instruction in Statistics Education (GAISE) Reports. Center for Statistics Education. American Statistical Association. Available online at <http://www.amstat.org/education/gaise/>.

Haley, Boyd E. Website. Department of Chemistry. University of Kentucky. Available online at <http://www.chem.uky.edu/research/haley/>.

JMP Software. Available online at <http://www.jmp.com/>.

Joint Statistical Meetings 2009 Website. ASA Meetings. American Statistical Association. Available online at <http://www.amstat.org/meetings/jsm/2009/index.cfm>.

Minitab. Available online at <http://www.minitab.com/>.

Moore, David S. *Statistics: Concepts and Controversies.* 5th ed. New York: W. H. Freeman and Company, 2005.

Moore, David S., and William I. Notz. *Statistics: Concepts and Controversies.* 6th ed. New York: W. H. Freeman and Company, 2006.

Murray, David, Joel Schwartz, and S. Robert Lichter. *It Ain't Necessarily So: How Media Make and Unmake the Scientific Picture of Reality.* New York: Rowman and Littlefield, 2001.

Napoleon's March. Posters and Graph Paper. The Work of Edward Tufte and Graphics Press. Available online at <http://www.edwardtufte.com/tufte/posters>.

The R Project for Statistical Computing. Available online at <http://www.r-project.org/>.

Resources: Model Courses. Science Education for New Civic Engagements and Responsibilities. Available online at <http://www.sencer.net/Resources/models.cfm>.

Rochefort, David A., editor. *Quantitative Methods in Practice: Readings from PS.* Washington, DC: CQ Press, 2006.

Rossman, Allan and Joan Garfield. Teaching Introductory Statistics: Activities, Technology, and Assessment. Two-day workshop, May 2001, Eastern Kentucky University, Richmond, Kentucky.

Special Interest Group on Statistics Education Website. Mathematical Association of America. Available online at <http://www07.homepage.villanova.edu/michael.posner/sigmaastated/>.

SPSS. Available online at <http://www.spss.com/>.

Tufte, Edward R. *The Visual Display of Quantitative Information.* 2nd ed. Cheshire, CT: Graphics Press, 2001.

Workshop Statistics Instructor Resource Website. Available online at <http://www.rossmanchance.com/ws/>.

Notes

[1]Gerd Gigerenzer discusses his attempt to verify Wells' ownership of the quotation in Chapter 9 of *Rationality for Mortals: How People Cope with Uncertainty* (New York: Oxford University Press, 2008).

[2]The Chance Project. Mathematics Department. Dartmouth College. Available online at <http://www.dartmouth.edu/~chance/>.

[3]David S. Moore, *Statistics: Concepts and Controversies.* 5th ed. (New York: W. H. Freeman and Company, 2005).

[4]Cynthia Crossen, *Tainted Truth: The Manipulation of Fact in America* (New York: Touchstone, 1996).

[5]David Murray, Joel Schwartz, and S. Robert Lichter, *It Ain't Necessarily So: How Media Make and Unmake the Scientific Picture of Reality* (New York: Rowman and Littlefield, 2001).

[6]Joel Best, *More Damned Lies and Statistics: How Numbers Confuse Public Issues* (Berkeley: University of California Press, 2004).

[7]Edward R. Tufte, *The Visual Display of Quantitative Information*, 2nd ed. (Cheshire, Connecticut: Graphics Press, 2001).

[8]David A. Rochefort, ed., *Quantitative Methods in Practice: Readings from PS.* (Washington, DC: CQ Press, 2006).

[9]Napoleon's March. Posters and Graph Paper. The Work of Edward Tufte and Graphics Press. Available online at <http://www.edwardtufte.com/tufte/posters>.

[10]Haley, Boyd E. Website. Department of Chemistry. University of Kentucky. Available online at <http://www.chem.uky.edu/research/haley>.

[11]Grayson, Trey. Kentucky Secretary of State Website. Available online at <http://apps.sos.ky.gov/secdesk/sosinfo/default.aspx?id=74>.

[12]Rossman, Allan and Joan Garfield. Teaching Introductory Statistics: Activities, Technology, and Assessment. Two-day workshop, May 2001, Eastern Kentucky University, Richmond, Kentucky.

[13]Workshop Statistics Instructor Resource Website. Available online at <http://www.rossmanchance.com/ws/>.

APPENDIX:

Section I. Syllabus

HONORS PROGRAM SYLLABUS

HON 304/HON 312 **3 credit hours**

Description

Florence Nightingale once said, "To understand God's thoughts we must study statistics, for these are the measure of his purpose." In this course, we will examine ways of summarizing and analyzing data, and we will discuss how statistical information influences our society and the way we function in it. We will study descriptive statistics, including numerical and graphical summaries of data; sampling; experiments; data ethics; assessment of statistics in the media; political polls; linear correlation and regression; government statistics; introduction to elementary concepts of probability; and an introduction to confidence intervals and hypothesis testing.

This course will present statistical concepts to students through current events, personal experiences, real-life applications, activities, and possibly guest lectures. There will be an emphasis on government statistics. Concepts will be emphasized over mathematical formulas, and software packages will be used.

General Education Goals and the Course

Students will be able to

- Use appropriate methods of critical thinking and quantitative reasoning to examine issues and to identify solutions (General Education Goal 2).
- Analyze the social and behavioral influences that explain how people relate to each other, to institutions, and to communities (General Education Goal 4).
- Distinguish the methods that underlie the search for knowledge in the arts, humanities, natural sciences, history, and social and behavioral sciences (General Education Goal 7).
- Integrate statistical knowledge that will deepen their understanding of, and will inform their own choices about, issues of personal and public importance (General Education Goal 8).

In particular, the General Education Objectives for achieving Goal 2 include the following:

1. Using mathematical methods to state and solve quantitative problems, including those stated in verbal form.
2. Using numerical and graphical data to make reasonable and valid conclusions.
3. Applying mathematical methods to real-life problems.

Course-Specific Student Learning Objectives

1. Students will demonstrate their ability to gather, synthesize, and critically analyze information in a well-written format. This will be verified through course assignments, quizzes, projects, and exams.
2. Students will demonstrate their understanding of statistics and its relationship to other areas of human concern. This will be verified through course assignments, quizzes, projects, exams, and a group presentation.
3. Students will demonstrate their understanding of government and its relationship to other areas of human concern. This will be verified through course participation, exams, projects, and a group presentation.
4. Students will verbally articulate complex information in an interesting presentation. This will be verified through class participation and a final group oral presentation.

Course Supplies

1. Texts

Statistics: Concepts and Controversies, 6th Edition, by David S. Moore & William I. Notz, 2006.

More Damned Lies and Statistics: How Numbers Confuse Public Issues, by Joel Best, 2004.

Quantitative Methods in Practice: Readings from PS, Edited by David A. Rochefort, 2006.

2. Other sources of information

Daily newspapers
Magazines
Websites
Visual Display of Quantitative Information, 2nd Edition, by Edward R. Tufte, 2001.

3. Calculator

A scientific calculator with statistical functions

Course Requirements and Grading Procedure

Activities/Participation	100 points
Quizzes (3)	150 points
Projects (Approx. 4)	200 points
Exams (3)	300 points
Group Project/Panel Presentation	100 points
Final Exam	150 points
Total	**1000 points**

Section II. Suggested Readings

Best, Joel. *More Damned Lies and Statistics: How Numbers Confuse Public Issues.* Berkeley, CA: University of California Press, 2004.

Moore, David S., and William I. Notz. *Statistics: Concepts and Controversies.* Sixth Edition. NY: W. H. Freeman and Company, 2006.

Rochefort, David A., editor. *Quantitative Methods in Practice: Readings from PS.* Washington, D.C.: CQ Press, 2006.

Tufte, Edward R. *Visual Display of Quantitative Information.* Second Edition. Cheshire, Connecticut: Graphics Press, 2001.

Some of the best discussions may focus on current articles taken from *The New York Times* or your local newspapers.

To find graphs that students can critique, see <http://www.usatoday.com/news/snapshot.htm>.

Section III. Discussion Questions

(Based on Suggested Readings)

Rochefort Chapter 10 (Questions written by Joseph Gershtenson)

Clinton, Joshua D., Simon Jackman, and Doug Rivers. "'The Most Liberal Senator'? Analyzing and Interpreting Congressional Roll Calls"

Concepts and Operationalization (Measurement)

In the afterword, Joshua Clinton says: "Measurement is central to political science" and that "quantifying political concepts is an extremely useful and informative endeavor."

What is the political concept that the authors are examining quantitatively in this article?

How is this concept quantified (operationalized)?

Can you think of other ways to measure the concept? Is there any ideal way to measure it?

Authoritative Numbers

Who is responsible for producing the (original) measure of ideology used in this article?

Would you regard the data produced as examples of authoritative numbers? Explain.

What types of potential problems with the numbers does Clinton identify in the afterword and how (if at all) do these relate to questions raised by Best in chapter 4 of his book?

Point Estimates and Confidence Intervals

What are point estimates? Give an example of a point estimate for a population parameter in a political science application unrelated to the ideology of members of Congress.

Why do the authors say that point estimates of senators' ideologies using the *National Journal* scores may be misleading (in terms of uncertainty associated with the scores)?

What can/should be done according to the authors to deal with this uncertainty?

What two factors affect the width of the confidence intervals for senators' ideologies?

Confidence Intervals and Interpretation

In what way does the use of confidence intervals change interpretations about which senators are more liberal/conservative?

Chapter 11

IS HONORS GENERAL CHEMISTRY SIMPLY MORE QUANTUM MECHANICS?

JOE L. MARCH

Introduction

Honors courses in the sciences present many challenges. Some of these challenges are the same as those that educators in the liberal arts face, but science courses, especially introductory-level courses, often have curricula that are well defined by external professional societies. Of the many introductory science courses, the general chemistry curriculum is fairly well defined by standardized exams, prerequisite knowledge for subsequent courses, and a relatively homogeneous set of available textbooks.

The increased emphasis on accountability to the public and accrediting agencies has led many institutions to use standardized exams as a simple assessment tool. In this context, standardized exams provided by the Division of Chemical Education of the American Chemical Society define the breadth of introductory topics that should be presented in first-year chemistry courses. Honors students are potential graduate or professional students, so they have a need for the content from the perspective of having standardized exams in their future (GRE, MCAT, DAT, or OAT). Additionally, a quick survey of the available general chemistry textbooks indicates that the curriculum has become homogenized, nearly all texts include the same set of topics in nearly the same order.

A homogenous set of topics is not entirely surprising. Chemistry is complex and students need to be introduced to the subject in some logical manner. As educators progress through the curriculum, the facts, equations, and concepts that come early in the term are integral to more advanced material as it is introduced. Students must be fluent in fundamentals before mastering the new, more complex principles introduced in upper-division courses.

Obviously honors courses are obligated to cover the fundamentals. Failing to present the fundamentals to highly motivated and highly prepared honors students would be unfair and unreasonable. These students, by selecting honors tracks, have essentially asked educators to present a course that allows them to expand their own personal horizons. But if educators are bound by this obligation for coverage, they must ask themselves what honors general chemistry is. More fundamentals? More content that others do not get? Would that be fair to the other students? Many more questions arise.

Educators must, of course, consider how others define honors. Friedman and Jenkins-Friedman provide a broad definition of honors education that crosses many institutions in many different disciplines. Honors is a commitment to an educational ideal. Key features often include academic experiences that are not met in traditional programs, the establishment of an environment that encourages aspirations and fosters achievement, and focused attention on academic excellence across the entire university community and not just in the honors program. By themselves, these ideals provide little concrete advice to those developing courses. Educators are still left to ponder if they should introduce more laboratory experiences and more topics. The *Journal of Chemical Education* has only offered minimal discussion of honors, but what has been written should provide some perspective on the types of activities included and the potential available.

Honors in Chemistry

One of the first publications on honors chemistry in the *Journal of Chemical Education* in 1928 describes a class where all chemistry students at Mount Union take the chemistry course together. At the end of the term, those students who have achieved above the class average are offered the opportunity to substitute a self-proposed laboratory assignment for the score on the final exam. The student is expected to propose a series of experiments, carry them out to fruition, and then provide a written report with analysis. This approach is not unlike many current inquiry or guided-inquiry approaches used across the country in many different settings.

Similarly, Newman, Atkinson, Fillinger and others describe special laboratory experiments for honors students. These experiments require more time and are potentially more complicated than many traditional verification laboratory assignments. While not entirely guided inquiry, these experiments model the research experience for honors students. As part of the approach, problems were presented to students in a manner that implied that the outcome was unknown and was sophisticated enough that the answer was not easily determined *a priori*. Again, contemporary educators might recognize these approaches as guided inquiry or problem-based laboratories. These modern approaches have been used in honors and non-honors classes with success.

Around 1960, Guenther surveyed chemistry departments in fifty liberal arts colleges. Nearly all (forty-eight out of fifty) indicated that student research was desirable as part of the honors program. The belief that research is an essential component of undergraduate science education is held in many departments, and calls for involving students in authentic scientific pursuits have been made by the National Academies of Science, the Council on Undergraduate Research (Boyd), and the Boyer Commission (Boyer 1998, 2002). Efforts to incorporate research in the first year have been made at many institutions,[1] but it is not clear that research has been the primary focus of the general chemistry laboratory sequence at any institution.

McHale and Porile have separately described the use of current events as a way to challenge honors students. Instructors expect students in these courses to integrate the general chemistry topics through writing assignments or exam questions that are based on topics that have likely appeared in the popular press. Students may be required to go to the primary literature, but more often instructors expect them to identify how chemical principles are applied to these current events. One of the desired outcomes is to help students recognize that general chemistry topics are not compartmentalized in the real world as they are in textbooks. This approach can manifest itself as either an extra writing assignment or as an attempt to have students develop their own personal concept map to see how a current event is related to the standard curriculum.

Maybe the most ambitious approach was described by Moore in 1972. He required students to learn the traditional material through independent study and then modified the lecture component to address the interests of his students. He provided students with an independent study syllabus and handouts that could be used to prepare for hourly exams. Students needed to master the material and pass a standard hourly exam at an eighty percent level. Voluntary study sessions with a faculty member were available, but class time was devoted to discussing "relevant complex compounds," "provocative humorous problems," and connecting general chemistry topics to current publications. Moore noted that the approach has merit in many settings and provides a set of diverse topics for discussion; however, Moore noted that this approach was most effective in small classes.

Parry and Willeford wrote about chemistry honors programs for the *Journal of Chemical Education* in 1962 as part of that journal's ChemEd Symposium series. The discussion chemistry educators are having today was just as difficult in 1962, and it appears that educators must, to a certain extent, pursue their own path. Parry and Willeford reviewed programs from many different types of institutions. Willeford's perspective is that chemistry honors students should be selected in the junior and senior years after students have gained a little experience on campus. Even in the 1960s, however, that perspective was changing with the addition of honors colleges and as some departments were adding courses in the freshman and sophomore years.

Parry looked at eleven prominent chemistry honors programs and described three key features common to all. First, successful honors programs selected their most effective teachers. Those departments that could identify their best instructors were often most successful. Second, honors involved some measure of selectivity. Students had to be ready and able to participate. Third, all eleven programs emphasized training students to do research. These descriptions provide guidance about honors programs in general, and they suggest that the process of research is an important aspect of training. They do not provide insight, however, for instruction in the general chemistry classroom where students may not have mastered content knowledge yet, and they do not really address the idea of whether or not honors general chemistry is for chemistry majors or for all honors students.

For a practical discussion on the topic, honors chemistry educators must return to Friedman and Jenkins-Friedman's conclusion: honors is a commitment to an educational ideal. Educators should agree that general chemistry contains a set of facts that students must know or understand. This set of facts is one basis for educators to measure success. The content mastery found in the traditional classroom is a good baseline for comparison, but honors education should be more than just the acceptance of facts.

Principles of Instruction for a General Chemistry Laboratory

Performing laboratory techniques is a learned skill, and many of these skills necessitate the development of fine motor skills that require repetition and patience. Students enrolled in general chemistry enter the laboratory with a wide range of previous laboratory experience. Some have had extensive experience, but for others this will be the first opportunity to handle common laboratory equipment. Thus, assigning the grade for a laboratory directly on the basis of how well students can perform a laboratory technique during the first laboratory period in which the technique is introduced is unfair to those students who do not yet have the skills to collect highly accurate data yet. This inequity can be rectified in two ways. The first method for responding to the lack of experience is for students to repeat the data collection process until they collect an acceptable set of data. By repeating the technique until an acceptable set of data is collected, students have the opportunity to correct gross errors in technique. Because of time-constraints on laboratories, this response is not always possible. To offset this time restriction, instructors can ask students to compare their own data to the data collected by other groups in the laboratory and to discuss the validity of the different sets of data. In this manner, students gain some experience with the equipment, although without the opportunity to perfect their technique, while drawing the anticipated conclusions from better data.

Chemistry instructors continue to struggle with balancing between technical skills and understanding. Instructors demand that students do their absolute best to collect an acceptable set of data, but they must also realize that their students' laboratory skills are still developing. At the freshman level, educators are shifting the emphasis of their chemistry courses to having students understand the concepts. Understanding the concepts is more valuable to the majority of students since those who will continue in a science-related subject will be required to practice and master laboratory skills throughout a four-year program and those who do not continue in a science-related subject will at least have a basic understanding of the concepts and practices used in science.

Having analytical skills will benefit students for many years to come. The ability to assess a situation and express the validity of the conclusions is important for all majors. With this in mind, chemistry instructors require that when a result or conclusion is made, the report or conclusion must be supported by data or accepted chemical principles. Students will have different levels of success at this point in their academic career; however, writing arguments that are based on real data collected under the supervision of an instructor is good practice.

Students analyze their data in two fundamental ways: they consider precision or they compare their results to other groups' results or an accepted result. Precision is determined by calculating the standard deviation or considering a simple linear regression analysis. Students are expected to use these numerical values to form the basis of their argument. Comparing results with other groups or an accepted answer should reveal the existence of gross errors and stimulate discussion. For example, when all of the students are determining the concentration of the same solution, the results for all of the groups should be similar. Students can discuss their own results and those of all of the other groups in the class. Thus, they often will have to discuss a gross error even when that error is made by someone else.

Once students graduate, they will quickly recognize that to be productive in the workplace, they will have to be able to express their knowledge to customers and co-workers. Obviously, expressing knowledge can take the form of oral presentations or writing. These communication skills are developed in the laboratory by requiring short laboratory reports and providing opportunities for student-student and student-instructor interactions. Laboratory reports are required for each experiment, and the instructions for these individual and group reports are specific. Each report includes an introduction, a results section, and an appendices section; some reports may also require an experimental section and an exercise section. Brevity is recommended because the report should be between one and two pages in length; they must also be grammatically correct and avoid wordiness. Of course, enough information must be included to indicate understanding. Students may discuss the data with classmates, but the report must represent their own understanding.

Student-instructor interactions are necessary for the success of the laboratory program. These interactions are stimulated by phrasing some of the report sections in an open-ended manner and by adding "Things to Think About" side-bars. Open-ended sections require the instructor to assess how well the experiment was performed before guidance is given to the students about how to proceed with the report. The discussions that occur because of the open-ended nature of the report allow the instructor the opportunity to probe the students' understanding and guide the students to a deeper understanding. The 'Things to Think About" side-bars prompt students to ask questions that will provide a better understanding of the material.

Honors General Chemistry Laboratory at UAB

With the knowledge of what others have done before and a commitment to an ideal, instructors at the University of Alabama at Birmingham (UAB) designed a general chemistry course. In designing the course, instructors thought about a research experience that requires writing and presenting on a chemistry topic connected to current events. The designers wanted to select students who were prepared to be successful and to offer outstanding instructors. Honors credit is only offered as part of the laboratory experience, which is a separate course from the lecture. This arrangement answers the content coverage question. All students in the lecture sequence see the same content and are tested in the same manner. The laboratory experience is founded on guided-inquiry experiments that all students complete, but more opportunities for using research-grade instrumentation, writing, presenting, and thinking are offered in the honors sections. The supplemental activities are described within this section.

The course starts with the traditional orientation about being safe and careful, handling glassware and other equipment, and adhering to common procedures. Honors students are asked to stay a little longer for two exercises. First, a drop of dye is placed in a beaker of water. Students are asked what observations they can make that would support the idea that molecules are moving and what observations would make the idea of molecules in motion difficult for others to believe. This discussion is relatively brief, yet it allows students to consider the power of a simple observation and the difficulty that others may have with the conclusions.

Then the class discusses the requirement of additional writing assignments. The traditional way to present laboratory reports is to have the instructor outline the parts of the report, indicating how to present numbers, tables, and figures. With honors students, however, instructors examine current research papers. These papers are not simply photocopied. Rather, the paragraphs and figures are cut out of the paper, and the pieces are put in a plastic bag. Each group is tasked with re-constructing the paper in some logical order. The subject matter of these papers is often beyond the student's knowledge base. Yet, most groups can identify paragraphs that go at the beginning, in the middle, and at the end. Having students simply piece the paper back together is not sufficient. They must explain how they knew how to order their paragraphs. For longer term retention, they are asked how they will use their observations to structure their first laboratory reports. In this way, the instructors have taken the idea of introducing the current literature to freshmen and provided an activity that they appear to be prepared to complete. They see how professionals write for journals that demand data and conclusions about the significance and meaning of that data.

In about week five, instructors provide the students with a sampling of the Concentrates section found in each issue of *C&E News.* These concentrates are short abstracts of recent work, but they are written for a general population of chemists. The content may be a little technical perhaps, but the articles are at a level where students can recognize the importance of the work. Each group then selects one research paper to present to the laboratory section during the last two weeks of the term, typically during the pre-laboratory part of the hour. Their presentations are brief, represent the students' understanding of the research, and speak to the level and understanding of the audience. Students present the big ideas and a chemical structure if it is relevant, and they briefly describe how the experiments are related to experiments they have performed as part of the general chemistry program. Because students have four to five weeks to work on this presentation, they have ample time to talk with their peers, teaching assistants, and instructors about how to make these connections.

Presentations are common experiences in the laboratories. One example involves the Milk Analysis laboratory. In this laboratory, students determine the amount of fat and calcium found in milk. They also observe qualitative tests for sugars. At the end of the period, each group is assigned a "current events" topic on milk. Examples include: What are the positive nutritional effects of drinking milk? What are the deleterious effects? What is the chemical structure of fats? Using no more than two slides, they present their findings during the next laboratory period.

Students also create their own research question related to water chemistry, propose an experimental design, and complete the measurements during the last month of the second-semester course. This project is discussed prior to spring break week so that students can collect water samples at locations away from campus. They are not limited to techniques performed during the year, but are supplied with a list of protocols that are most commonly proposed (*i.e.*, water hardness, phosphate concentration, dissolved oxygen). Projects have ranged from complex (water quality in a lake) to simplistic (water hardness from different drinking fountains). Students are responsible for defending their sampling techniques, sample storage and handling, and any conclusions they reach.

Conclusion

Developing a general chemistry laboratory course for honors students requires balancing the need for content mastery and laboratory skills. Making honors general chemistry accessible to students who will not become chemistry majors requires considering these students' interests and expectations. The decision to offer honors only in the laboratory ensures content coverage and provides opportunities for students to develop important skills that are broader than just a chemistry course. The literature has described honors experiences largely targeted at the junior or senior level, but there is national interest in providing first-year students with an authentic research experience. The program developed for use at UAB incorporates best practices from prior reported approaches including inquiry, writing, presenting, and open-ended research-type activities. The general chemistry laboratory at UAB presents students with exercises that prepare them for future coursework in chemistry or other disciplines.

Bibliography

Atkinson, G.F. "Analytical Chemistry for Honors Applied Chemistry Students." *Journal of Chemistry Education* 46, no. 8 (August 1969): 519–521.

Boyd, Mary, and Jodi Weseman. *Broadening Participation in Undergraduate Research: Fostering Excellence and Enhancing the Impact.* Council on Undergraduate Research, Washington, D.C., see <http://www.cur.org/publications.html> (accessed May 2012).

Boyer Commission on Educating Undergraduates in the Research University, S. S. Kenny (chair). *Reinventing Undergraduate Education: A Blueprint for America's Research Universities.* State University of New York–Stony Brook, 1998.

Boyer Commission on Educating Undergraduates in the Research University, S. S. Kenny (chair). *Reinventing Undergraduate Education: Three Years After the Boyer Report.* State University of New York–Stony Brook, 2002.

Fillinger, Harriett H. "The Effect of Temperature on Reactions in Gels—An Honors Course Problem." *Journal of Chemistry Education* 25, no. 2 (February 1948): 102.

Freshman Research Initiative (FRI). University of Texas at Austin. <https://fri.cns.utexas.edu/> *(accessed May 2012).*

Friedman, Paul G., and Reva C. Jenkins-Friedman. "Fostering Academic Excellence Through Honors Programs." *New Directions for Teaching and Learning 25*, San Francisco: Jossey-Bass, 1986.

Guenther, William B. "Chemistry Honors Programs in Liberal Arts Colleges." *Journal of Chemical Education* 39, no. 3 (March 1962): 118–120.

McHale, Jeanne L. "Current Events as Subjects for Term Papers in an Honors Freshman Chemistry Class." *Journal of Chemical Education* 71, no. 4 (April, 1994): 313–314.

Meyers, Chet. *Teaching Students to Think Critically.* San Francisco: Jossey-Bass, 1986.

Moore, William E. "Multidimensional Approach to Teaching Honors Freshman Chemistry." *Journal of Chemical Education* 49, no. 2 (February 1972): 134–135.

Newman, Melvin S. "Synthesis of O-acetylbenzoic Acid: An Experiment for an Honors Organic Laboratory Course." *Journal of Chemical Education* 54, no. 3 (March 1977): 191.

Pappenhagen, L.A. "Honors Problem in Quantitative Analysis." *Journal of Chemical Education* 5, no. 1 (January 1928): 94–95.

Parry, R.W. "Chemistry Honors Programs in Universities." *Journal of Chemical Education* 39, no. 3 (March 1962): 114–118.

Porile, Norbert T. "Cold Fusion as the Subject of a Final Exam in Honors General Chemistry." *Journal of Chemical Education* 66, no. 11 (November 1989): 932–933.

Undergraduate Research Opportunity Program, University of Michigan, <http://www.lsa.umich.edu/urop/> *(accessed May 2012).*

Undergraduate Research Initiative, University of Alberta, <http://www.uri.ualberta.ca/> (accessed *May 2012).*

Raths, Louis Edward. *Teaching for Thinking: Theory, Strategies & Activities for the Classroom.* 2nd. New York: Teachers College Press, 1986.

Swartz, Robert J. and David N. Perkins. *Teaching Thinking: Issues and Approaches.* Pacific Grove, CA: Midwest Publications, 1990.

Willeford, Bennet R., Jr. "The Development of Honors Programs in Chemistry." *Journal of Chemical Education* 39, no. 3 (March 1962): 110–113.

Notes

[1]Paul G. Friedman and Reva C. Jenkins-Friedman, "Fostering Academic Excellence Through Honors Programs." *New Directions for Teaching and Learning 25* (San Francisco: Jossey-Bass, 1986).

[2]L. A. Pappenhagen, "Honors Problem in Quantitative Analysis." *Journal of Chemical Education* 5, no. 1 (January 1928): 94.

[3]Melvin S. Newman, "Synthesis of O-acetylbenzoic Acid: An Experiment for an Honors Organic Laboratory Course." *Journal of Chemical Education* 54, no. 3 (March 1977): 191.

[4]G. F. Atkinson, "Analytical Chemistry for Honors Applied Chemistry Students." *Journal of Chemistry Education* 46, no. 8 (August 1969): 519.

[5]Harriett H. Fillinger, "The Effect of Temperature on Reactions in Gels—An Honors Course Problem." *Journal of Chemistry Education* 25, no. 2 (1948): 102.

[6]William B. Guenther, "Chemistry Honors Programs in Liberal Arts Colleges." *Journal of Chemical Education* 39, no. 3 (March 1962): 119.

[7]Freshman Research Initiative, University of Texas at Austin, <https://fri.cns.utexas.edu/>, Undergraduate Research Opportunity Program, University of Michigan, <http://www.lsa.umich.edu/urop/> Undergraduate Research Initiative, University of Alberta, <http://www.uri.ualberta.ca/>.

[8]Jeanne L. McHale, "Current Events as Subjects for Term Papers in an Honors Freshman Chemistry Class." *Journal of Chemical Education* 71, no. 4 (April 1994): 313.

[9]Norbert T. Porile, "Cold Fusion as the Subject of a Final Exam in Honors General Chemistry." *Journal of Chemical Education* 66, no. 11 (November 1989): 932.

[10]William E. Moore, "Multidimensional Approach to Teaching Honors Freshman Chemistry." *Journal of Chemical Education* 49, no.2 (February 1972): 134.

[11]R.W. Parry, "Chemistry Honors Programs in Universities." *Journal of Chemical Education* 39, no. 3 (March 1962): 114.

[12]Bennett R. Willeford, Jr., "The Development of Honors Programs in Chemistry." *Journal of Chemical Education* 39, no. 3 (March 1962): 110.

SECTION IV:

SCIENCE IN HONORS FOR THE SCIENCE STUDENT

Chapter 12

COMMUNICATING SCIENCE: AN APPROACH TO TEACHING TECHNICAL COMMUNICATION IN A SCIENCE AND TECHNOLOGY HONORS PROGRAM

CYNTHIA RYAN, MICHELE GOULD, AND DIANE C. TUCKER

Many students of science and engineering struggle with the relevance of core writing courses and approach an English composition sequence with some mixture of trepidation and disinterest. Researchers, scientists, and engineers working in the academy and in the private sector, however, emphasize that written and oral communication skills are essential to success. The University of Alabama at Birmingham (UAB) responded to this apparent disconnect by designing a technical communication class within the context of a required introductory English course; this course has become a foundational course in UAB's Science and Technology Honors Program. Virtually all students acknowledge that the course is extremely valuable and view it as a key component of their preparation for upper-level courses and research involvement.

A Thematic Honors Program in Science and Technology

In fall 2005, UAB launched a thematic honors program in science and technology. The Science and Technology Honors (STH) Program capitalizes on UAB's strength as a major biomedical research university and attracts students preparing for careers involving research and development. An overarching goal of the STH Program at UAB is preparing students to become scientific leaders. To accomplish this, the STH Program involves students in interdisciplinary coursework alongside intensive mentored research. As Appendix A illustrates, each component makes a unique contribution to the students' training but also overlaps with the other components. For example, during the mentored research component, students draw on their backgrounds in scientific communication, information from their interdisciplinary seminars, and experiences in laboratory methods. This model assumes that the confluence of an interdisciplinary perspective, experience in research, and scientific communication skills will prepare students to pursue careers as the generators of new knowledge in their fields, setting the stage for their emergence as scientific leaders.

Given that the overall objective of the program is preparing students for creative and original scientific thinking, the curriculum must offer students more than content in their particular scientific disciplines. For example, STH courses examine the relationship between the questions scientists pursue and the methods they select. To pursue questions of this type, students must be equipped to analyze scientists' arguments and to critique their conclusions. In addition, students identify the assumptions and limitations of each approach to a problem. The Scientific and Technical Communication course provides an important foundation for the rigorous critical thinking that characterizes an emerging scientific leader.

The Role of Writing in the STH Program Curriculum

In each STH course, students are required to communicate orally and in writing. Reading and interpreting scientific journal articles is the focus of the Introductory Seminar. Writing assignments in the Introductory Seminar include both analysis of the journal article and preparation of a poster that explicates the key figure. As the students progress through the STH curriculum, they apply the skills learned in their Scientific and Technical Writing class to prepare formal research proposals and to write the journal article that presents their honors thesis research.

Creating a Writing Course for Science and Technology Honors Students

While the authors knew from the start that they wanted students to learn the basics of good scientific writing, which are clarity, conciseness, coherence, and the conventions of scientific argument, they also wanted to offer a sophisticated and realistic perspective on how communication in all its forms influences scientific thought. Before designing the Scientific Communication Course, the authors considered three issues that may apply in varying degrees to other academic institutions and honors programs:

- compliance with the requirements for second-semester freshman composition, as outlined in the Quality Enhancement Plan (QEP) in place at UAB. (See <http://main.uab.edu/sites/DOE/QEP>.)
- consistency between the approach to analyzing and producing scientific discourse in this course and other courses that incorporate writing in the STH curriculum.
- instruction in basic principles that govern all communication as well as discipline-specific considerations in fields ranging from engineering and chemistry to psychology.

Recognizing the centrality of scientific communication in the success of aspiring scientists, the authors developed the Scientific and Technical Communication course described here. They discussed the structure and the content of the course to increase its coherence with the goals of the STH Program and to ensure that the principles described below were followed. Echoing their working model that scientific thinking and scientific writing are interrelated, complementary processes, the authors found themselves revising the course as they learned more about students' responses to the course and to the theory and practice of scientific inquiry across the curriculum.

Principle I: Communication is Context-Specific

While the authors agreed on certain characteristics of effective communication, they also recognized that getting the point across depends on the situation. To convey their ideas convincingly throughout their academic careers and into their professional lives, students and scientists must understand that all forms of communication, whether written, oral, or visual, are shaped according to context-specific factors:

- audiences = the intended readers or receivers of a message. (In scientific communication, the level of expertise required to understand the information is particularly important; students must acknowledge the differences between expert, lay, technical, or managerial audiences and consider the various disciplinary perspectives that influence individuals within each category.)
- purposes = the intended aims of the communicator (to inform, to persuade, to motivate, or to entertain).
- textual features = the conventions for content and format of particular types of communication (IMRAD organization for a journal article and stylistic features such as syntax, tense, and voice).

Principle II: Communication is a Problem-Solving Process

Rather than adopting the perspective that scientific inquiry is active and that writing up the results is a passive afterthought, the authors convey the message to students that communication is a dynamic and strategic problem-solving process. To reinforce this model, they introduce the following parts of the communication process and offer frequent practice for honing problem-solving skills:

- exigency = the problem that writers identify and that makes communication necessary in the first place.
  - What is the gap/question/issue driving communication?
  - How urgent and/or significant is this gap/question/issue?
  - Is the gap/question/issue narrow enough to address adequately?
- resources = the sources of data that address the identified gap/question/issue.
  - What evidence has been identified for locating answers?
  - Is the range of data types, such as primary or secondary research, sufficient?
  - Which audiences might contribute needed perspectives on the gap/question/issue?
- organization = the determination of which ideas and evidence to include or exclude from the planned communication.
  - Which data are most effective in addressing the exigency?
  - What kinds of information will the audiences for the message expect or value?
  - What sequence of ideas will best build the argument?
  - How will these audiences use the data? Is the information accessible to audiences for this use?
- style = the presentation of ideas.
  - What kinds of words and sentences work best for reaching the targeted audience?
  - What purposes need to be achieved?
  - How can the ideas on the page be made more accessible: easier to locate, understand, and apply?

- assessment = evaluation of the problem-solving process.
  - What criteria can be used to evaluate how thoroughly the problems in this context have been examined, how the information has been collected and arranged to answer the existing questions, and how receptive the audience is to the communication?
  - What could have been done differently to produce better results?

One distinction between this problem-solving approach to communication and traditional approaches to teaching introductory composition courses is the emphasis on student-centered inquiry in connection to the writing process, a necessary focus for students who aspire to be scientific leaders in their chosen fields. The questions within each category stem from each student thinking actively about the source and form of a particular message. In traditional composition courses, students are frequently provided the answers to these questions as guidelines for composing a document. STH students are engaged in the problem-solving aspect of communication throughout the semester.

Principle III: Scientific Writing and Scientific Thinking Work in Tandem

Scholars have long written about the inseparability of thought and language,[1] and the work of scientists is no exception.[2] The ability to develop appropriate terminology, formulate concise hypotheses, and produce detailed descriptions is central to making sense of scientific work.

This course encourages students to consider thinking and writing as overlapping processes. As each of the three principles outlined above suggests, the writing course developed specifically for the STH Program challenges students to reconsider any preconceptions they might have about thinking and communicating as linear processes. The authors seek to introduce students to the "web" model of communication advocated by Lewenstein[3] in which ideas and messages from a variety of sources (some technical, some organizational, and some popular) merge to make meaning in a particular disciplinary field.

The influence of human and social factors in the framing of scientific questions is an aspect of scientific inquiry's dependence on context that is often overlooked. The scientific method is generally viewed as an objective means of inquiry that is assessed through the lenses of reliability and validity; however, decisions about which questions to ask, about the investigational methods used, and about how to interpret the results occur within a social, cultural, and historical context that introduces an element of subjectivity. The authors believe that it is crucial that students who are pursuing careers in science and technology understand that scientific inquiry and communication are influenced by the broader social and historical context.

The assignments described in the following section illustrate some of the ways the authors teach students to examine science and communication as complex and interlocking processes while helping them to identify specific, focused strategies for participating productively in this web of information.

From Principles to Pedagogy

While the course that emerged from these principles is multi-layered, two sample assignments illustrate how the authors' approach plays out in the classroom. The first is a case writing assignment that requires students to apply problem-solving skills to a scenario posing a range of ethical issues. The second is a sampling of prompts for a semester-long journal assignment that involves a focused consideration of the connections between scientific thinking and scientific writing.

Collaborative Case Writing

Students begin the semester with an assignment that introduces them to communication as a problem-solving process. Although this assignment can be pursued individually, a group approach is preferable for a number of reasons. First, cases are intended to place students in realistic settings in which communicators must take into account both the complementary and conflicting interests of different parties. Secondly, students are better able to analyze the range of parties and interests involved in a specific scenario by discussing the case from different perspectives. One characteristic of effective writers is their ability to consider the needs of multiple readers. Opportunities for exchanging ideas allow students to develop strategies for thinking through the complexity of representing multiple points of view in a writing task. Lastly, collaborative assignments prepare students to work as teams in the workplace and complement the group assignments being completed in other courses in the STH program.

The sample case writing assignment included here focuses on the topic of tissue donation. (See Appendix B). The instructions for the assignment require the students to work through a series of steps and receive feedback from other groups and from the instructor. At each stage, groups simultaneously expand their understanding of the complexity of the case while selectively narrowing their approach to a specific aspect of the case to which they can respond through writing. By considering the many layers and dimensions of parties, issues, and implications before committing to a specific written document, students respond to the case from an informed position. Extensive analysis leads to more thoughtful communication: thinking precedes and coincides directly with writing since composing is a process of advancing knowledge by determining what needs to be communicated, to whom, and for what purpose. Collaboratively, students brainstorm ideas relating to the complexities of the case scenario both face to face and electronically, produce multiple drafts of the documents required for completion of the assignment, and provide written feedback to one another within their case groups as well as to other teams working on the same assignment in the class.

In brief, the case assignment provided more extensively in Appendix B presents students with the varied interests at stake in a scenario involving collection of tissue samples from patients undergoing surgery in a hospital setting (Duke University Medical Center) and the subsequent banking of these samples at a biotechnology company called Arias Corporation. A plethora of procedural and ethical issues are suggested in the case description, and students are placed in the position of negotiating the rights of patients who may be vulnerable decision-makers, the commercial interests at play in the partnership between Duke and Ardais (there is no legal restriction on selling human tissue), and the benefits and potential risks of human tissue research for individual patients and their families as well as for the general good.

Throughout the case assignment, students engage in strategic communication. For instance, discussions guide students through the many communication steps that might be needed to address a particular problem. Since most of these problems are too complex to solve through a single written document, the students brainstorm the implications of choices about what to communicate and how these choices fit into their larger plan for responding to the issue. In the tissue donation case, for example, a group might develop the following seven-step strategy for addressing Duke University Medical Center's public position on tissue donation. Although the letter to patients (step 4) is the only document that each group must compose in its entirety, the inclusion of accompanying steps reflects students' understanding of the multiple, intertwined processes involved in problem-solving of this caliber: from research to written communication to oral exchanges. Here are the seven steps:

1. review existing promotional material from Duke University Medical Center.

2. identify key values Duke stresses in this material.
3. schedule several meetings with hospital staff, ethical review boards, and public relations personnel to discuss and develop continuity between Duke's public image and the relationship it has established with Ardais.
4. compose a letter to patients of Duke University Medical Center that expresses the facility's image and the ways in which the work it conducts with Ardais is consistent with this image.
5. follow through with a carefully planned procedure for requesting tissue donations from patients.
6. periodically conduct training sessions to review with hospital personnel the proper procedures for requesting tissue donations from patients.
7. annually review the policy and procedures regarding tissue donation to ensure compatibility with Duke University Medical Center's mission.

While each group is required to think through a multi-layered strategy for responding to the narrowed problem they have selected, they must also compose one of the documents identified in this strategy. In the previous seven-step strategy, the group might compose a letter to patients (step four), keeping in mind the concerns of other parties mentioned in the overall analysis. For instance, the group must consider what kinds of persuasive appeals might be most appropriate for the patient audience that also coincide with the facility's reputation. Also, students must adopt a particular role for the letter writer, such as that of an administrative or health care provider, and think about the parties who should receive a copy of the letter. The group takes into account further questions such as who else might eventually read the letter (e.g., a patient's insurance company, a lawyer, or a family member), and what strategies in content and format should be applied to ensure the most favorable response from these readers.

The strategy statement that students submit with the document they have composed, in this instance, a letter to patients, is as important to the assignment as the letter itself. This statement demonstrates a group's broader understanding of the numerous interests that must be considered when communicating and highlights specific choices in the text including word choices, organization, and strategic rhetorical appeals that accommodate this complexity.

Scientific Discourse Journal

A second key assignment is an individual journal to which students contribute throughout the semester. One of the central goals of the journal is to collect several different kinds of writing into a single text:

- an informal analysis of an abstract.
- a revision of an existing abstract alongside a commentary of the changes made and why.
- analysis of a letter to the editor of a science journal and a response to this letter with consideration of the forum (listed and implied guidelines for contributors to the journal) for the conversation.
- an annotated bibliography for an upcoming research project that includes three possible criteria for clustering the sources.
- notes from an on-campus seminar that STH students attend for a Research Approaches course as well as a summary of the speaker's main ideas and an assessment of the speaker's presentation style.
- a list of ideas resulting from brainstorming begun collaboratively in class and completed individually at home.
- analysis of a science-based article written for a public audience with suggestions for rewriting the piece to incorporate sounder science without losing audience interest.

The purpose of encouraging students to create a montage of types of writing, some traditionally classified as scientific and some viewed as less conventional, is to disrupt students' notions of scientific thinking and scientific writing as separate processes. Instead, they are encouraged to view all kinds of communication written for an audience of themselves, their classmates, a teacher, a professional scientist, and so on as part of a larger process of thinking through language about science.

At the end of the semester, students hand in the journal along with a written analysis of what they think the journal reflects about their thinking and writing skills in a particular scientific discipline. This reflective activity is an effective way to tie up the course from a more personal perspective because students are using their own ideas and words to situate themselves as students of science and future professionals. The critical stance students develop through these and other exercises is a key component of their preparation for future success in research and development.

Critical Thinking in the Classroom

As students in STH approach scientific material, whether contemplating a current study published in a professional journal, reviewing their lab notebooks regarding a recent experiment, responding to a conference presentation given by an expert in their field, or sharing news about a scientific discovery announced on the front page of *The New York Times*, the authors have learned to embrace the opportunity to encourage critical thinking. The questions that follow require students to think about *why* and *how* science is communicated in particular ways, whatever the circumstances.

1. Who is the specific audience for a given text, and for what purpose is the audience being presented with this message? How do the audience and purpose vary from those of other texts on a similar topic?
2. How does the author or presenter situate the message about science in a broader conversation? What previous scientific knowledge is mentioned? What gap in existing knowledge is offered? In what ways is new knowledge, or the need for new knowledge, made significant to the audience? What makes the message timely and relevant?
3. Focusing primarily on the author's argument (and less so on the scientific facts included in a particular message), assess the strength of the claim. Is it logical, backed by sufficient evidence, adequately framed by existing studies, etc.?
4. Why might a published or presented article have been selected for a specific journal, conference, or other forum? Which criteria established for members participating in this particular community have been met? Which criteria are less effectively met?
5. How might a researcher's central research question be shifted slightly, worded differently, investigated alternatively? In what ways might the outcome of the research change as a result?

Conclusion

Student response to the Scientific and Technical Communication course has been extremely positive: students acknowledge that they are "working very hard" but realize that they are learning skills and principles that they "will actually use" as they move forward. Because the ability to communicate effectively is essential for success in scientific or technical arenas, Scientific and Technical Communication is a core course in the STH Program curriculum. Three foundational principles are woven through the course: communication is context-specific; communication is a problem-solving process; and scientific writing and scientific thinking work in tandem. Students emerge from this course with a strong foundation in scientific writing and presentation, but they are also beginning to appreciate the importance of rigor in thinking and of the validity of multiple perspectives applied to complex problems. Additional courses and research experiences build upon this foundation as the students move through the program and into their graduate studies.

Suggested Readings

In addition to the cited references, the following theoretical and pedagogical texts are helpful for designing a scientific and technical writing course for honors students:

Gregory, Jane, and Steve Miller. *Science in Public: Communication, Culture, and Credibility.* Cambridge, MA: Basic Books, 1998.

Harris, Randy Allen, ed. *Landmark Essays on Rhetoric of Science: Case Studies.* Mahwah, NJ: Lawrence Erlbaum Associates, Inc., 1997.

Pauwels, Luc, ed. *Visual Cultures of Science: Rethinking Representational Practices in Knowledge Building and Science Communication.* Hanover, NH: Dartmouth College Press, 2006.

Penrose, Ann M., and Steven B. Katz. *Writing in the Sciences: Exploring Conventions of Scientific Discourse.* 3rd ed. New York: Pearson, 2010.

Bibliography

Burke, Kenneth. *A Rhetoric of Motives.* Berkeley: University of California Press, 1969.

Fahnestock, Jeanne. "Accommodating Science: The Rhetorical Life of Scientific Facts." *Written Communication* 15, no. 3 (July 1998): 330–350.

Foucault, Michel. *The Archaeology of Knowledge and the Discourse on Language.* New York: Pantheon-Random, 1972.

Lewenstein, Bruce V. "From Fax to Facts: Communication in the Cold Fusion Saga." *Social Studies of Science* 25, no. 3 (August 1995): 403–436.

Nelkin, Dorothy. *Selling Science: How the Press Covers Science and Technology.* New York: W.H. Freeman, 1995.

University of Texas-Arlington Online Course Management System Website. Available online at <https://honors.uta.edu/secure/credit>.

Notes

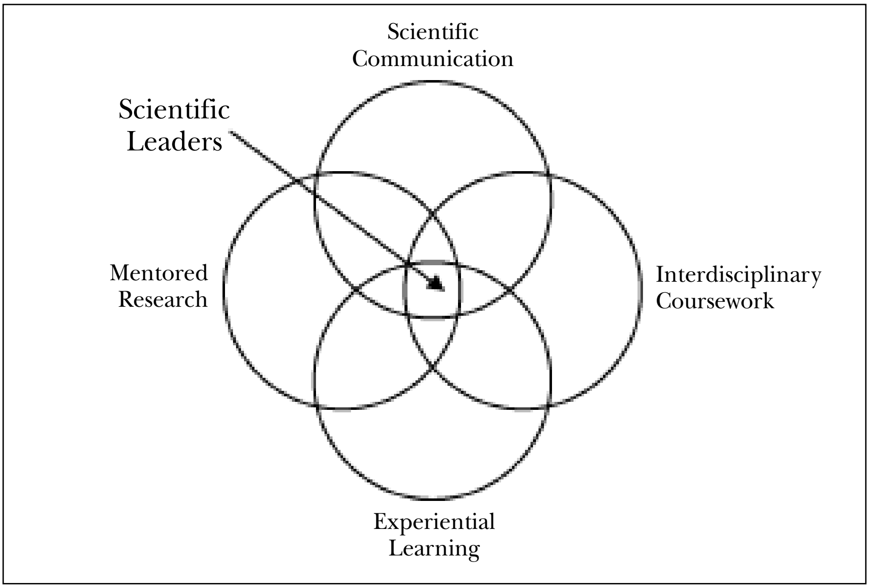
[1]See Kenneth Burke, *A Rhetoric of Motives* (Berkeley: University of California Press, 1969); Michel Foucault, *The Archaeology of Knowledge and the Discourse on Language* (New York: Pantheon-Random, 1972).

[2]See Jeanne Fahnestock, "Accommodating Science: The Rhetorical Life of Scientific Facts," *Written Communication* 15, no. 3 (July 1998): 330–350; Dorothy Nelkin, *Selling Science: How the Press Covers Science and Technology*. New York: W.H. Freeman, 1995.

[3]Bruce V. Lewenstein, "From Fax to Facts: Communication in the Cold Fusion Saga," *Social Studies of Science* 25, no .3 (August 1995): 403–436.

APPENDIX A:

Figure 1: Preparing Students as Leaders: Science and Technology Honors Program



APPENDIX B:

Collaborative Case Assignment: "Tissue Donation"

For the first major assignment, you will respond in small groups to a scenario involving a range of parties, communication issues, and ethical questions. (See Attachment: Collaborative Case Scenario that follows the assignment requirements.) The goals of this assignment are to analyze thoroughly the problems and questions suggested by the scenario:

- identify and describe the parties invested in these issues while addressing the particular "stake" each has in the scenario;
- agree on a particular response to one or more of these parties;
- strategize and compose a written document aimed toward select audiences for specific purposes;
- create a strategy statement that outlines these choices and justifies your approach to the document.

Additionally, you'll have the opportunity to work as a team with your classmates, and we will discuss some of the approaches to collaborative decision-making and writing that you might adopt.

Step I: Invention
The first task to be completed when addressing a case is to analyze extensively the many factors presented in the case, both explicitly and implicitly. Each member of the group should brainstorm responses to the following questions, and then groups will share their responses to create a "master list" of considerations.

- What are the problems/gaps/issues/questions suggested by the case?
- What "categories" can be devised for grouping these questions? For instance, are some financial issues, some biomedical issues, some procedural issues? You may see overlaps between the categories, but grouping them will help you to sort out the many possibilities.
- Who are the parties involved or invested in these categories of issues? Include parties that are named directly (e.g., the medical centers, the name of the tissue donation organization, and particular roles such as doctors, patients, hospital nurses, etc.).
- How would you characterize each party? What might be the party's interests, level of expertise, values, concerns, and so on?

- What organizational factors might be relevant to your response? What might be the concerns of the hospital or Ardais in terms of economics, public image or reputation, logistics of working out the tissue donation plan, etc.?
- What values and trends in the larger culture might influence the issues you've outlined? How?

Your responses to these questions can be handwritten in list form, but they should be extensive (several pages in length). Thinking through the complexity of the case will help you to develop better documents later.

Step II: Decision-Making

Once your group has shared individual responses to the questions, discuss how you would like to proceed. You have a number of decisions to make:

- Which "type" of issue do you want to pursue (e.g., financial, biomedical, public relations, patient rights, etc.)?
- What role will you assume as the writer?
- What kind of message do you want to convey, and to whom?
- What other kinds of communication might precede or follow this message?
- What approach to this message will you take? Will the document be a letter, memo, survey? What kinds of features will the document have? What will you need to pay particular attention to (e.g., wording, organization, tone, etc.)?
- What do you anticipate will be the response to this document(s)?

Step III: Compose a Document(s)

As a group, compose the document(s) you have planned. We will discuss in class some of the "logistical" ways of writing as a team, and you will have several opportunities to share your drafts with one another and with other groups in the class before handing in the final portfolio.

Step IV: Write a Strategy Statement

The last step in the assignment is to produce a strategy statement explaining your group's approach to the assignment. This document will be in memo format, include headed sections to mark off various parts of your strategy, and be approximately 1-1½ single-spaced pages in length.

We will discuss the proper format for memos, letters, and other possible documents you might be working with as we progress through the assignment.

Make sure you keep all notes, drafts, and responses to your team's work. In the final portfolio for the assignment, all of these materials will need to be labeled and included.

Attachment: Collaborative Case Scenario: Tissue Donations
(Case prepared by Robert F. Ladenson, Department of Philosophy, Illinois Institute of Technology, 2001)

In early Fall 2000, Beth Israel Deaconess Medical Center (Boston) and Duke University Medical Center were the first of several health care facilities to enter into a partnership with Ardais Corporation, a biotechnology company. Ardais Corporation's stated goal is to accelerate understanding of the links between certain genetic patterns and disease, and so improve clinical applications by facilitating better diagnosis, drug development, and treatment. Ardais will create a tissue bank to provide genetic researchers with disease-specific tissue and detailed patient information to enable researchers to link specific genetic sequences with diseases such as cancer, heart disease, and neurological disorders. Ardais plans to "systematize and standardize the collection and processing of high quality clinical materials and associated information." Ardais will then provide biological materials that would otherwise be discarded as medical waste, process them into usable samples, and make them available to researchers.

Prior to surgery, patients will be asked by a hospital nurse if they would be willing to donate tissue samples left over from their surgery to the tissue bank. To prevent the possibility that additional tissue will be removed for the purpose of providing samples, surgeons will not know which patients have consented. All patient information will be anonymous, protected by a rigorous coding system. The hospitals will sell this tissue to Ardais. Ardais in turn will sell the patient information to biomedical researchers. Ardais will also receive license fees.

Although sale of human organs is illegal in the United States, no similar legal restriction applies currently to the sale of human tissue. The medical community, at this time, has not discussed extensively either the morality of selling human tissue, or, assuming that such sales are morally permissible, the question of who might share in the profits.

Before our next class meeting, jot down your thoughts on the following. We'll start our discussion of the case with your ideas.

- Who are the parties affected, either directly or indirectly, by this scenario?
- What are the ethical issues suggested in the scenario?
- What part does communication play in this scenario?

Chapter 13

DESIGNING INDEPENDENT HONORS PROJECTS IN MATHEMATICS

MINERVA CORDERO, THERESA JORGENSEN, AND BARBARA A. SHIPMAN

Mathematics in the Honors Curriculum

According to the National Collegiate Honors Council, the curriculum of a fully developed honors college should offer significant course opportunities across all four years of study, constitute at least twenty percent of a student's degree program, and require an honors thesis or project.[1] At the University of Texas at Arlington (UT Arlington), the most commonly offered courses for satisfying mathematics requirements are Honors Calculus I, Honors Calculus II, and an honors mathematics course for non-mathematics majors. Because of the minimum requirements for enrollment set by the university, offering stand-alone upper-level honors mathematics courses is often unfeasible. Honors students majoring in mathematics and those interested in higher mathematics satisfy the honors credit requirements by "contracting" several of their upper-division mathematics classes and by completing an honors thesis project. This paper addresses the design and implementation of these upper-level honors mathematics experiences at UT Arlington, including providing guidance for constructing honors mathematics contracts and for mentoring a student in writing an honors thesis in mathematics.

Expectations of an Upper-Division Honors Experience in Mathematics

The following components comprise the core of the upper-division honors experience in mathematics at UT Arlington: *Individualized Learning:* An honors contract or research experience in mathematics should provide opportunities for one-on-one collaboration between the mentor and the student. *Research Practice:* The honors experience should provide guidance on formulating a problem that can be investigated in the given time frame and on searching for research literature related to the problem. *Professional Communication Skills:* The honors experience should provide direction on preparing a professionally written mathematical document, designing explanations appropriate for given audiences, and using technology to attain these goals. *Professional Development:* The honors experience should include interactions with the faculty mentor about graduate studies in mathematics, applying for jobs, and what to expect in either an academic or applied career.

Honors Contracts in Mathematics Courses

At UT Arlington, the process of creating an honors contract in a non-honors course starts at the beginning of the semester when the instructor and student meet to discuss the student's interests and goals. A formal contract detailing the requirements and timeline of the project is signed by the instructor and the student and filed in the honors college. Another option, a group contract, can offer unique opportunities for honors students to engage in a collaborative mathematical experience that results in a final project incorporating various viewpoints. Two sample honors contracts are included in the Appendix. Example A is designed for a group of students while Example B is a contract of a different flavor for one or more honors students.

At UT Arlington the process of creating an honors contract is implemented through an online system managed by the honors college.[2] The student has the option at any time to back out of the project and complete the class as a non-honors course. At the end of the semester, the instructor evaluates the student's work and signs off on the honors credit, contingent upon a grade of B or higher in the course.

Honors contracts come in many varieties. One type of contract requires the student to produce a paper that delves more deeply into a topic in the class that has sparked the student's interest. For example, an honors student in a recent section of Analysis I at UT Arlington investigated the formal development of the real number system, starting with the formal definition of an integer, leading to the definition of a rational number and then to Dedekind cuts, which yield the real number system. Such a paper can also mention or discuss problems in the subject that are not yet solved.

Another type of honors contract that expands students' views of the mathematical world is structured around exposure to the mathematics literature. Journals that are suitable for honors mathematics majors to tackle include the *American Mathematical Monthly, The Mathematics Magazine, The College Mathematics Journal,* and the *Notices* or the *Bulletin of the American Mathematical Society.* The instructor may ask the honors students to read articles from one or more journals of this type that are related to the course and write a synopsis of each article, explaining what its purpose is and how the mathematics and concepts tie in with and expand upon what was done in class. Examples of articles include "The Historical Development of Infinitesimal Mathematics,"[3] which is appropriate for a course in calculus or analysis; "Pythagorean Triples and Inner Products,"[4] which is suited for a course in modern algebra or linear algebra; "Lifting the Curtain: Using Topology to Probe the Hidden Action of Enzymes";[5] "Do Dogs Know Calculus of Variations?"[6] and "Do Dogs Know Related Rates Rather than Optimization?"[7] The latter two work well together for a differential equations course.

In a course such as linear algebra or differential equations taught without a computer lab component, course assignments and examples are restricted to problems with simple numbers and small enough dimension so that calculations can be done reasonably by hand. This arrangement precludes many real-world applications, such as those with large number parameters where the coefficients are experimentally measured quantities that may not be nice integers. An honors contract can be designed around two or three applications, perhaps taken from problems in industry, biology, or computer science, whose solutions rely heavily on computer implementations of techniques learned in the course. The honors students write a synopsis of each application, explaining the problem to be solved, how the mathematics is used to model the problem, and how the computer helps in obtaining the solution. Ideally, this project will include an explanation of the underlying mathematical strategy behind how the software was programmed to obtain the results.

A more traditional approach for an honors contract in mathematics is to have the honors students work each week on problems that are carefully selected by the instructor to broaden or deepen their understanding of the course material. To prevent this type of honors contract from becoming just more of the same, these problems can be taken from sources in which the course material is applied to other fields of mathematics or other disciplines, thus extending the student's understanding of the interconnectivity of disciplines. The honors students will present their solutions orally each week to the instructor. The instructor may also select some of these problems for the students to present to the class two or three times during the term. If the project is an effort by a group of honors students, then all of the students in the group should be present at each meeting in which oral presentations are given.

Finally, the fact that the course is not itself an honors course can be used positively. In almost every mathematics course, some students struggle to learn the material and keep up with the homework. Here the honors students have a unique opportunity to communicate mathematics by leading several working sessions during the semester, possibly before course exams. Thinking about how to explain mathematics to others is both challenging and mathematically enlightening for honors students. In consultation with the instructor, honors students prepare sessions in which they guide the students as they work with each other in solving selected problems. For example, at UT Arlington, a contract honors student conducted a study session each week in Analysis I, which the UT Arlington Chapter of the Mathematical Association of America sponsored. Both the students in the class and the honors student mentor matured mathematically from this experience and enjoyed working together. Another example of a clever way to utilize upper-class mathematics honors students as mentors for other students can be found in Crans and Rovetti.[8]

Because an honors contract entails work that spans a semester-long course, the process should not be compromised by starting late. Requests for honors contracts after the first week of classes should be rejected. To keep students on task throughout the semester, instructors should plan and hold meetings at least biweekly. At each meeting, the assignment for the next meeting should be explicit. Like all students, honors students procrastinate on serious projects if not guided properly. Keeping the honors students on a schedule with regard to writing the paper is important. Approximate dates for final presentations of the project to the class, the instructor, or any other audience should be set at the beginning of the semester. Having a schedule will help students to keep the goal in sight and will promote a sense of urgency about completing the project on time.

Developing an Honors Thesis

The culminating experience of the UT Arlington Honors Program is the preparation of an honors thesis, usually during the final two semesters of the degree. The penultimate semester features a course on research methods, in which students select an area of interest, pose potential questions to be investigated, and collect and study background material with a view toward seeking strategies that may aid in answering some of the questions. During the final semester, students continue their work toward a professionally written document and an oral presentation.

The research course leading to the honors thesis is perhaps the most difficult part of the project. Mentors should not dictate a direction to students since this tactic can stifle creativity and cause students to lose interest in their project. During this stage students will find that talking to other faculty, in mathematics or outside the department if the paper involves other disciplines, is helpful. Communicating with several faculty members is one of the best ways for students to encounter viewpoints related to their work that they may not have considered before. The best strides during this phase of the work occur when the students have an insight of their own and excitedly want to tell others about what they have discovered. Here is where the thesis problem emerges and becomes the true work of honors students.

To facilitate the shaping of ideas during the research course, mentors should hold regularly scheduled meetings with students, ideally on a weekly basis. The work to be completed by the next meeting should be clearly stated. During this stage, mentors should provide guidance on how to proceed with a literature review, including finding journal articles using electronic searches such as *MathSciNet*. Often the students may be interested in a general topic but may have no specific question or problem in mind. To extract a tractable project from these studies, mentors should suggest two or three possible directions for students to consider, the goal, of course, being the selection of a specific direction for the work of the final semester.

An honors thesis can come in different flavors and forms. For example, a thesis may be an analysis of existing research literature to support a hypothesis of the student regarding a particular problem in mathematics or mathematics education. A recent honors graduate whose goal is to teach mathematics in the secondary schools had, through his own experiences in learning mathematics, put much thought into how to motivate students to overcome mathematics anxiety and approach mathematics with an eagerness to learn. In his honors thesis, the student structured his ideas into a systematic method that teachers can use in the classroom to motivate students in high school algebra. The plan was informed by and supported by research-based teaching techniques through a careful literature review.

A thesis may also investigate the relationship between a mathematical model and the physical situation it describes. One paper by a recent honors student at UT Arlington examined the role of Lie theory in the development of the standard model of particle physics. Here, the mathematical structure of representations, developed independently of any physical application, led physicists to predict the existence of further elementary particles that were later found experimentally. The thesis traced the historical beginnings of particle physics and the independent development of Lie theory and explained how the mathematics guided the discovery of the underlying organization of elementary particles and their properties.

Another type of honors thesis is the practical implementation of a known theorem. For example, a recent honors graduate with an interest in algebra and a talent for programming worked with a faculty member in commutative algebra to implement a theorem, recently proved by that faculty member, regarding the support sets of certain modules. The theorem was constructive in its proof. The honors student learned the mathematics underlying the theorem and then learned the computer algebra system Macaulay 2. Utilizing Macaulay 2, the student wrote a program that takes in a support set and puts out a module with that prescribed support set.

Alternatively, a thesis could provide original examples or proofs of known concepts or theorems in mathematics. For instance, in "Equivalence of the Ext-Algebra Structures of an R-module," the honors student considered two distinct definitions of the Ext-Algebra structure. One description was through the co-homology of a projective resolution, and the other through equivalence classes of exact sequences of finite lengths (extensions). No readable treatment of the equivalence of these two algebraic constructs was available in the modern literature. The thesis gave a detailed proof of the equivalence. In the process, the honors student uncovered an as-yet-undetected error in the second edition of a standard textbook used in graduate courses on this topic. The mentor asked the honors student to take the initiative to contact the author of the book, who was most grateful and formally thanked the student in print. In another project, entitled "Quadric Systems in Projective Three-Space," the student constructed new examples of four-dimensional, base-point free quadric systems in P^3 whose projectivization contains a pre-specified finite number of elements of rank at most two and explained the methods used to construct these systems.

An honors thesis may also take current mathematical results and extend them. In a project entitled "Characterizing Wavelet Sets under Varying Dilation Factors," the honors student took part in a Research Experience for Undergraduates, where she spent a summer studying wavelet sets. A dilation d wavelet set is a set that tiles $\mathbf{R}$ via translations by 2π and tiles $\mathbf{R}/\{0\}$ by dilations by powers of d. During that summer, the student learned that wavelet sets with a dilation factor of two have been studied in detail. For her thesis project, she extended these known results to include different dilation factors and also considered the concept of a dual dilation factor in which two different dilation factors are used simultaneously.

Whatever the form of the project may be, each honors thesis should display the unique signature of an honors student, offering readers the carefully organized and original work of a creative thinker.

The Written Thesis

Throughout their honors courses and contracts in mathematics, students should have received training on how to write mathematics with precision and clarity. Now the mentor's role is to guide the writing of the paper so that its meaning and content are clear and complete. While there is flexibility in the structure of the paper, any thesis should include the following components: *Introduction:* The introduction should state the context of the thesis. What is the question or issue that will be addressed? From whence does it arise? What are the broader implications of this investigation? *Background and Definitions:* This component should review the essential literature required for a full appreciation of the thesis. Necessary definitions should be given explicitly, with accompanying examples where appropriate. *The Heart of the Thesis:* This section is where the meat goes. *Conclusions:* This section should not be simply a summary of the thesis. Rather, it should offer a perspective on what comes after the thesis, including any ideas for future investigations. *References:* This component should contain a complete list of all the resources cited in the thesis and should not include references that are not cited.

The Oral Presentation

Mentors should spend time helping students with good presentation techniques. This will include discussions on the appropriateness of the amount of material to be presented, what the audience may or may not already know, how to make slides clean and readable, and talking directly to the audience rather than reading a prepared speech. Mentors should also discuss how to handle questions from the audience, including those to which presenters may not have an immediate answer. The students should do a practice run of the presentation to an audience who is friendly and not intimidating.

Giving a good presentation on mathematics is a significant challenge. The students' presentations are not modeled after those given in typical mathematics conferences, where the speaker loses most of the audience in the first few minutes. For any given audience, the entire talk, except for the last few minutes, should relate to what the audience knows, building the concepts and ideas up in their minds so that they can appreciate what is being done. At these presentations the first third of the talk develops the context of the problem, giving concrete examples to illustrate what is being investigated. The second third describes the approach to solving the problem or addressing the question, without giving the solution or final conclusions. The last portion of the presentation will provide the big picture, including solutions, without much focus on technicalities. (For some practical advice on giving a good talk on mathematics, refer to McCarthy's "How to Give a Good Colloquium."[9])

Conclusion

An upper-division honors education in mathematics begins with students who have learned creative and disciplined ways of understanding and communicating mathematics and who are ready to enter a setting closely akin to that of professional mathematicians. Through a variety of honors contracts and the completion of an honors thesis, students gain valuable hands-on and heads-on experience in collaborating with peers and professional mathematicians, investigating research-level mathematical questions, and preparing and giving high-quality presentations to a variety of audiences. These steps are necessary to prepare students for the options they may choose after graduation, whether it be in the applied work force, academics, or teaching.

Bibliography

Crans, Alissa S., and Robert J. Rovetti. "Beyond Formulas: A Collaboration between Liberal Arts Honors Underclassmen and Senior Math Majors." *Honors in Practice* 7 (2011): 115–126.

Dickey, Leonid A. "Do Dogs Know Calculus of Variations?" *College Mathematics Journal* 37, no.1 (January 2006): 20–23.

Gallian, Joseph A. Contemporary Abstract Algebra, 7th ed. Belmont, CA: Brooks/Cole, 2010.

Gerstein, Larry J. "Pythagorean Triples and Inner Products." *Mathematics Magazine* 78, no. 3 (June 2005): 205–213.

Laugwitz, Detlef. "On the Historical Development of Infinitesimal Mathematics." *American Mathematical Monthly* 104, no. 7 (August/September, 1997): 654–663.

McCarthy, John E. "How to Give a Good Colloquium." Available online at <http://www.ams.org/ams/gcoll.pdf>. Accessed June 1, 2012.

National Collegiate Honors Council website of honors program recommendations: <http://www.nchchonors.org/basichonorsprogram characteristics.shtml> Accessed 10 April 2012.

NOVA: The Proof. Directed by Simon Singh, produced by Paula Apsell. WGBH Boston, 1997, DVD/VHS.

Perruchet, Pierre and Jorge Gallego. "Do Dogs Know Related Rates Rather than Optimization?" *College Mathematics Journal* 37, no. 1 (January, 2006): 16–18.

Sumners, De Witt. "Lifting the Curtain: Using Topology to Probe the Hidden Action of Enzymes," *Notices of the AMS* 42, no. 5 (1995): 528–537.

Notes

[1]<http://www.nchchonors.org/faculty-directors/basic-characteristics-of-a-fully-developed-honors-college/> See characteristics 8 and 9. Accessed 10 April 2012.

[2]The UT-Arlington online course system is available at <http://www.uta.edu/honors/documents/credit.pdf>.

[3]Detlef Laugwit, "On the Historical Development of Infinitesimal Mathematics," *American Mathematical Monthly* 104, no. 7 (August/September 1997): 654–663.

[4]Larry J. Gerstein, "Pythagorean Triples and Inner Products," *Mathematics Magazine* 78, no. 3 (June 2005): 205–213.

[5]De Witt Sumners, "Lifting the Curtain: Using Topology to Probe the Hidden Action of Enzymes," *Notices of the AMS* 42, no. 5 (1995): 528–537.

[6]Leonid A. Dickey, "Do Dogs Know Calculus of Variations?" *College Mathematics Journal* 37, no. 1 (January 2006): 20–23.

[7]Pierre Perruchet and Jorge Gallego, "Do Dogs Know Related Rates Rather than Optimization?" *College Mathematics Journal* 37, no. 1 (January 2006): 16–18.

[8]Alissa S. Crans and Robert J. Rovetti, "Beyond Formulas: A Collaboration between Liberal Arts Honors Underclassmen and Senior Math Majors," Honors in Practice 7 (2011): 115–126.

[9]John E. McCarthy, "How to Give a Good Colloquium." Available online at <http://www.ams.org/ams/gcoll.pdf>.

APPENDIX:

Sample Honors Contracts

Example A
An honors contract in real analysis for a group of two to four students.

Purpose: To investigate and explain the rigorous foundations of the real number system with a view toward its historical development.

Project Description: Students will prepare a collaborative report. Students will find and study literature on the foundations of the real number system to address this sequence of questions:

- How are the positive integers rigorously defined?
- What algebraic structure does the set **N** of positive integers have?
- How are these algebraic operations defined?
- How is **N** extended to the set **Z** of all integers?
- What properties (axioms) does **Z**, together with its algebraic structure, satisfy?
- How is the set of rational numbers, **Q,** defined as an extension of **Z**?
- What algebraic structure does **Q** have, and how are the operations defined?
- What is the system of axioms satisfied by **Q** and its algebraic structure?
- Explain the structure of **Q** as an ordered field.

How is a real number defined? There are different ways in which this can be done. Be sure to investigate Dedekind cuts, as well as other ways of extending **Q** to **R**. How are the different methods of extending **Q** to **R** related historically? How can one see that they are equivalent?

Resources: At least five different reliable texts and/or articles should be used in an integral way. The following will be helpful:

Electronic databases and searches: Electronic resources, such as *MathSciNet* and *Academic Search Complete,* host a wide spectrum of literature, including journals, books, and theses, for specified key words, topics, or authors. They can be found in the research resources on university library's website.

Science and Engineering Library: Librarians who specialize in searching for mathematics literature can help you locate resources.

Inter-library Loan (ILL): If a resource that you have identified is not available in the university's library, you may borrow from another library through ILL.

The Report: The honors group will write a report, at least 15 pages typed and single-spaced. The report must be written in good English and should have well-organized sections. The explanations should be carefully written to be understood by an audience of typical students of Analysis I, and the mathematics must be correct and explained well. The ideas should be supported by relevant and instructive examples crafted by the honors students writing the paper. The report should include a bibliography of references that includes at least five sources used significantly in the paper. The references should be cited within the body of the text where they are used.

Timeline: Student schedule for a 14-week course.

Week 3: Have at least five good references selected. Present to the instructor a brief summary of how each of these references will be used in the paper.

Week 5: Have a vision of the overall structure of the paper. Have a general understanding of each of the selected references. Present to the instructor a preliminary outline of the paper and indicate where each reference will be used.

Week 7: Explain the details of the paper through the algebraic structure of **Z**. Include instructive examples. Focus on presenting the material in a way that exhibits a working understanding of the material, stated in your own words, with your own examples.

Week 9: Present the details of the paper through the structure of **Q** as an ordered field.

Week 11: By the eleventh week, you will have found different ways of constructing **R** as a complete ordered field. Give a careful chalk presentation of these constructions to the instructor and be prepared to explain their equivalence.

Week 12: Present a preliminary final written report to the instructor for comments and suggestions, which will be incorporated into your final paper. The instructor will discuss the basics of good presentation style with you in preparation for the oral presentation to the class.

Week 14: The final report is due the last week of classes, before the final exam.

During this week, your group will give a presentation of the project to the class.

Example B

An honors contract in abstract algebra.

(Note to the reader: This contract is written for an honors student in an undergraduate abstract algebra course that covers rings and fields.)

Goal: Through this project, the student will appreciate the ongoing nature of abstract algebra as a dynamic and developing field of mathematics.

Project Description: The student will read biographies of mathematicians from *Contemporary Abstract Algebra* by Joseph Gallian and choose three mathematicians whom they find interesting. The chosen biographies should be associated with the beginning, the middle, and the end of the course (for example, one from ring theory, one from vector spaces, and one from field theory), and they should not all be from the same generation; in particular, at least one should be a contemporary mathematician.

For each chosen mathematician, the students will read an original research paper by the mathematician and an article about their mathematics. The second article may be a review article in a journal or a chapter in a book. Students will have about four weeks to study each pair of papers. Reading the review article first may be most helpful.

For each of the three original research papers, students will write a careful synopsis that addresses the following questions:

- What is the problem being studied?
- What is the context of the problem?
- What is the author's strategy for solving the problem?
- How does this paper fit into the big picture of abstract algebra?

The review article about this author's mathematics will help to answer the last question. Students will meet each week with the instructor to discuss the content of their papers.

The Presentation: At the end of the semester, the honors students will give a mathematical presentation on their project to the class. The students may focus on one mathematician or incorporate all three into a coherent whole. Rather than presenting a formal talk, the students should lead a series of activities to engage the class in the mathematics. For example, the students may present to the class a simple-looking question and give their classmates a few minutes to think about how to solve it. Such an activity can lead into the problem being investigated in one of the research papers.

Chapter 14

HONORS SENIOR THESES ARE ABET FRIENDLY: DEVELOPING A PROCESS TO MEET ACCREDITATION REQUIREMENTS

MICHAEL DORAN

Introduction to ABET

ABET[1] is currently the main accreditation agency for programs in science, technology, engineering, and mathematics (STEM). ABET traces its origin to the 1930's and has undergone mergers and revisions during its history. In the past, ABET stood for Accreditation Board for Engineering and Technology, but recently the organization's name has been changed to ABET without a specific meaning for the letters. Also, in the past, a subdivision of ABET, CSAB, would focus on issues of computing accreditation. CSAB ceased to exist when ABET was renamed and restructured, and all computing accreditation now falls under the supervision of ABET.

Introduction to University of South Alabama

Since its inception, the University of South Alabama (USA) Honors Program has included students of all majors across the university student population. A central focus of the program is to foster an environment of undergraduate research. One clear and visible way to accomplish this research objective is by the successful completion of an honors senior thesis by all students in the honors program. Since any qualified students, regardless of their major, can be part of the honors program, the question of discipline capstone projects quickly became an issue. This requirement was especially problematic when the disciplines were subject to ABET accreditation reviews and evaluations. The main programs falling under ABET criteria are those in Engineering and Computing.

The USA academic programs in computing are housed in the School of Computing (SoC). This distinct academic unit, with a dean reporting to the Senior Vice President for Academic Affairs, provides a rather unique environment for computing. Most universities will distribute computing across several academic units on campus, such as Engineering, Business, or Arts and Sciences. Being housed in one academic unit not only provides a visible computing identity but also provides many advantages regarding accreditation process and procedures. At USA, the College of Engineering (CoE) is a separate academic unit that administers a variety of traditional Engineering degrees.

I currently serve as the Director of the USA Honors Program. Before assuming this role, I served as the Coordinator (Chair) of Computer Science for fourteen years with the rank of Professor of Computer Science. The USA Honors Program was created in 1999 with 30 students and included a Computing major. At the time the honors program was being formed, the Computer Science (CS) degree had been ABET accredited (CSAB subdivision at the time) since 1987. The Information Science (IS) major had been one of the first to be accredited in the 1990s. The newly defined Information Technology (IT) major was still being formed, and all measures were taken to assure it would meet future accreditation criteria. Each degree included a capstone senior project experience. In 1999, since the CS major had been through two additional successful accreditation and review cycles, the other two computing majors of IS and IT both adopted the existing senior capstone project experience. As the honors program was being formed, the academic units were considering how senior thesis credits would fit within their curriculum.

At the time the SoC had a year-long senior capstone project. These courses also used to satisfy the Writing Across the Curriculum (W) requirement for all degrees. This course sequence was numbered 497/498, and the classes were designed to be taken in the last two semesters of a student's course of study. Seeking uniformity, the honors program asked each academic unit and department to add an honors W course to be numbered 499. In the SoC the faculty agreed to support this request by substituting the two 499H courses for the 497/498 sequence. SoC had three years to prepare for the initial implementation of this sequence.

ABET Outcomes

ABET defines various student outcomes that all graduates of a program must meet by the time they successfully graduate from an academic degree program. Each of the computing disciplines has nine common outcomes labeled A through I. In addition, each specific degree of CS, IS, and IT have other specific outcomes that must be met. CS has two more, J and K; IS has one more, labeled J; and IT has five more, labeled J through N. The nine shared outcomes, A through I, follow:[2]

A. "An ability to apply knowledge of computing and mathematics appropriate to the discipline."

B. "An ability to analyze a problem and identify and define the computing requirements appropriate to its solution."

C. "An ability to design, implement, and evaluate a computer-based system, process, component, or program to meet desired needs."

D. "An ability to function effectively on teams to accomplish a common goal."

E. "An understanding of professional, ethical, legal, security, and social issues and responsibilities."

F. "An ability to communicate effectively with a range of audiences."

G. "An ability to analyze the local and global impact of computing on individuals, organizations, and society."

H. "Recognition of the need for an ability to engage in continuing professional development."

I. "An ability to use current techniques, skills, and tools necessary for computing practice."

The initial curriculum models used for accreditation were defined by the Association for Computing Machinery (ACM). Dating back to the 1960s, these ACM curriculum models would often focus on specific courses.[3] In 1991, ACM started modifications to the curriculum that veered from the course-driven model to what were termed knowledge units.[4] The knowledge units, however, were then combined into groups that looked very much like the traditional courses found in the previous ACM curriculum models. In some cases the numerical labels (CS1, CS2, CS3 . . .) would be present throughout the curriculum, literature, and accreditation process. Starting around 2000,[5] ACM and subsequently ABET extended the ideas presented by the knowledge units, evolving from a course-driven model of evaluation to an outcomes-based approach. This change necessitated that a wide array of artifacts be developed to show that students accomplished these outcomes. Prior models were driven by common courses. Now the expectation was that these outcomes would be distributed throughout the entire curriculum. Each program was responsible for accomplishing this integration and distribution. The manner of assessment was likewise left to each program although each one was required to provide evidence that graduates would achieve a target level of mastery by the end of their degree. To produce this evidence, the SoC at USA adopted a common senior capstone project experience covering a two-semester sequence. The activities of the capstone courses and project would focus on A through I, the shared ABET outcomes.

Honors Senior Thesis

The honors senior thesis is a process that really should start from the first day the student joins the university. Research is the central focus of the USA Honors Program, and it is an ongoing process that students pursue within their discipline. This culture of scholarship starts with the first course although the actual research in the discipline must certainly rely on a maturity gained by the completion of the more advanced courses of study.

To foster this culture of research, the honors program has created honors seminars that students are required to take each year. Freshmen and sophomores take HON 101 and 201 as a one-credit hour seminar. In these courses, students discuss the role and importance of research and practice various research skills. These courses require students to become aware of and actually complete an application for undergraduate research or a national scholarship. The process and importance of research become a clear objective of members in the honors program.

A third seminar, HON 301, is required of the juniors in the honors program. At this stage of the degree, students should have acquired the necessary discipline maturity and knowledge to successfully and actively engage in a research agenda. Also, based on the experiences in HON 101 and 201, students have commonly participated in a research experience. This research experience often occurs in a funded summer program supported by the university. Many students also take advantage of Research Experience for Undergraduates (REU), extramural funding and study abroad opportunities to gain this research experience.

HON 301 is also a one-credit-hour seminar in which the students must complete an approved thesis prospectus. This course can be taken either fall or spring semester, but scheduling this class in the fall semester certainly has its advantages. Writing the prospectus during the fall term allows students to use the spring semester to engage in focused research and to prepare for the thesis process. It is also a simple fact that a thesis is not a punch-the-clock experience. Being enrolled in courses of 1, 2 or 3 credit hours does not necessarily correspond to the demands of working on a thesis. Depending on project pacing and events, students might need to engage in 3 hours of work one week or 12 the next if that is what is required to accomplish the task. When a student completes HON 301 in the fall, the subsequent spring can be a valuable momentum-building experience. Once students understand the time requirements of the research process, they often use that spring to continue work by participating in a directed study or similar course options. The thesis is a viable and valuable part of the learning environment, and students typically view it as an opportunity and not as a burden. In the case of Computing and Engineering, however, students easily and logically integrate these seminars and the 499 sequence into the existing capstone project experience.

SoC Capstone Project

During the past twenty years, many approaches to how this project course could be implemented have been presented at various CS education conference.[6 7 8 9] Although various themes have included games, industry partners, and service learning, a constant aspect was the role played by teams of students to include this capstone experience to explore a large-scale project. Now, because the evaluation process must focus on the student outcomes that specifically address the ABET outcomes A-I, the SoC modified the existing capstone sequence to feature these presentations.

The SoC capstone project was a two-semester sequence (497/498) that also satisfied the W requirement of the university. The usual approach was for students to take these courses in the final two semesters of their course work. The goal of this capstone project sequence was to have soon-to-graduate students engage in a large-scale, real-world project. Working in teams, students would take a problem from initial conception to full deployment. Students often had to acquire some degree of domain-specific knowledge to accomplish the tasks of the project and might involve non-SoC faculty. In some instances, members of the local computing industry would propose a project and work with the students. Obviously, these experiences with industry partners were particularly meaningful. In some cases these students were then hired by the industry partner, an added benefit of the course for all involved. A focus on service learning was also an element in some projects. These service-oriented projects would often occur within the academic environment by providing technical service for the SoC as well as other academic units on campus. These non-SoC tasks would allow the students to explore the impact of computing on other disciplines and required a degree of immersion into those environments. In all projects, a SoC faculty would serve as a group's mentor. The role of this mentor was not only to provide any technical guidance needed but also to assure that academic component of the project was maintained. Working with the course instructor, these mentors would provide valuable assistance in determining that the necessary ABET outcomes were being met and the academic artifacts were produced. Even when working with industry professionals, everyone involved understood that the academic integrity of the course would be the absolute priority and the process, not the product, was the ultimate goal.

The courses were structured to provide sufficient observation and feedback to students so that the proper process was always being employed. After teams were formed and projects defined, a clear system of accountability was established. Regular meetings with instructor and mentors were central to this process to assure that the academic objectives were being met, that feedback was being given, and that corrective measures were initiated when necessary. This group experience and the structured meetings addressed most of the ABET A through I outcomes. With the creation of the artifacts and the regular observations by faculty, a rich and accurate array of assessment measures were gathered for each team and for every student engaged in the projects. All projects were professionally presented in an open forum attended by all the students and faculty involved in the courses, and these presentations were, of course, evaluated. All of the people involved in these projects participated in an end-of-semester assessment based on the ABET rubrics.

Because of the mandate to satisfy all the ABET outcomes, including the non-project-based outcomes, the project was not the only exercise or activity of the course. The social, historical, career, and leadership issues were mostly addressed by guest speakers, class readings, class discussions, and field trips. In most cases, the resulting artifact was a reflection paper. These papers were evaluated according to writing rubrics, and each student would collect them into a writing portfolio. Student often used these portfolios during the interview and graduate application process. A practical result of having a portfolio was often that the students would receive job offers or graduate school admission and funding.

By the end of the process, a wealth of information was available for assessment and review by the USA faculty and by the ABET visiting teams. This data is stored in a data repository for long-term review and comparison. Collected and analyzed over many years, the evaluation data revealed that the ABET outcome targets were being met.

A postscript to this discussion is that the senior capstone project has now been reduced to a single semester. This change was implemented for a variety of reasons, some of which were nonacademic. Obviously the scope and complexity of projects have been modified to fit this shortened schedule.

Mapping the Honors Thesis to Capstone Project

The honors thesis is a six-credit-hour, two-semester course sequence. building directly upon a prospectus-preparation course during the junior year. The thesis is the research effort of a single individual, which might appear to be at odds with the group experience central to computing and most STEM capstone experiences. Working with a mentor, honors students would identify an area within the group project that could be researched by the individual student during a short period of time, perhaps through a directed study or summer research experience. This product will form the basis of the honors thesis and at the same time be integrated into the larger capstone project, thus benefitting the non-honors group members of the capstone project.

Beyond contributing the thesis to the capstone project, honors students assume the role of project manager. Of course, a key element of any large project development is the project management. This role not only ensures the successful completion of the process leading to the final project but also encourages honors student to mentor the other group members. The value of peer mentoring and tutoring cannot be understated.[10] [11]

The capstone experience developed by USA certainly satisfies the critical element of having students participate in a large team project that produces a comprehensive document. The course structure likewise includes meeting the requirements of ABET outcomes A-I. The thesis prepared under the guidance of the mentor and committee contributes to the capstone experience while fulfilling the research requirement that is essential to the work done by students in the USA Honors Program.

One Size Now Fits All—Engineering Agrees

After the successful use of this approach by the SoC, discussion ensued with the College of Engineering. Some Engineering departments and the previous dean would require students in honors to complete an honors thesis as well as their Engineering capstone team project. The current dean was very open to the dual use of the honors thesis to also satisfy the capstone projects. Using the successful ABET reviews of the SoC, the dean was now able to convince the Engineering faculty that this approach was in compliance with ABET guidelines. Over the years there have been few honors students in both Engineering and Computing. Previous ones in Engineering have done both a thesis and capstone project. In the academic year 2011–2012, with the complete support of the dean and the various department chairs, an engineering honors student used this combined model for his capstone project sequence as well as his honors thesis. He successfully used EE 499 (6 credit hours) to substitute for his 2 credit hours of EE 401 and 3 credit hours of EE 404. There was an unused hour, but this option was viewed as better than the alternative of doing two projects and having an unused 6-credit-hour thesis sequence. By proper project management and task activities, he was able to contribute to his team effort as well as satisfy the individual components required by the honors thesis.

Bibliography

ABET. "Criteria for Accrediting Computing Programs, 2012–2013. <http://abet.org/comuting-criteria-2012-2013/>

Austing, Richard H. et al., eds. "ACM Curriculum Committee on Computer Science Curriculum 78: Recommendation for the undergraduate program in Computer Science." *Communications of the ACM* 22 no. 3 (March 1979): 147–166.

Carpenter, Jr., Thomas E., Adair Dingle, and David Joslin. "Ensuring capstone project success for a diverse student body." *Journal of Computing Sciences in Colleges* 20, no. 2 (December 2004): 86–93.

Daigle, Roy J., and Michael V. Doran. "Facilitating Bloom's Level One through Active Learning and Collaboration." *Journal of Information Systems Education* 9, no. 3 (Winter 1998): 3–6.

Doran, Michael V., Roy J. Daigle, and Robert A. Robertson. "Beyond the Classroom: Mentoring in the CIS Academic Community." *Journal of Information Systems Education* 9, no. 3 (Winter 1998): 15–18.

Huang, Timothy. "The game of go: an ideal environment for capstone and undergraduate research projects." *SIGCSE'03: Proceedings of the 34th SIGCSE Technical Symposium on Computer Science Education, February 19–23, 2003, Reno, NV*: 84–88.

Joint Task Force on Computing Curriculum, eds. "Computing Curriculum 2001." *Journal of Educational Resources in Computing* 1 no. 3 (September 2001): 1–240.

Leidig, Paul M., Roger Ferguson, and Jonathan Leidig. "The use of community-based non-profit organizations in information system capstone projects." *ITICSE'06: Proceedings of the 11th annual SIGCSE Conference on Innovative and Technology in Computer Science Education, June 26–28, 2006, Bolonga, Italy*: 148–152.

Sandra, Jacob, R. Miller, and Bandon J. Howe. "Developing realistic capstone projects in conjunction with industry." *SIGITE '07, Proceedings of the 8th ACM SIGITE Conference on Information Technology Education, October 18–20, 2007, Destin, Florida*: 27–31.

Tucker, Alan, et al., eds. "Computing Curricula 1991." *Communications of the ACM* 34 no. 6 (June 1991): 69–84.

Notes

[1]ABET, "Criteria for Accrediting Computing Programs, 2012–2013, <http://abet.org/comuting-criteria-2012-2013/>. The website provides ABET information.

[2]ABET, "Criteria for Accrediting Computing Programs, 2012–2013," <http://abet.org/comuting-criteria-2012-2013/>. The website provides the accreditation criteria and standards for assessment. The specific outcomes A-I are listed.

[3]Richard H. Austing et al., eds., "ACM Curriculum Committee on Computer Science Curriculum 78: Recommendation for the undergraduate program in Computer Science," *Communications of the ACM* 22 no. 3 (March 1979): 147–166.

[4]Allan Tucker et al., eds, "Computing Curricula 1991," *Communications of the ACM* 34 no. 6 (June 1991): 69–84.

[5]Joint Task Force on Computing Curriculum, eds., "Computing Curriculum 2001," *Journal of Educational Resources in Computing* 1 no. 3 (September 2001): 1–240.

[6]Thomas E. Carpenter, Jr., Adair Dingle, and David Joslin. "Ensuring capstone project success for a diverse student body," *Journal of Computing Sciences in Colleges* 20, no. 2 (December 2004): 86–93.

[7]Sandra Gorka, Jacob R. Miller, and Bandon J. Howe, "Developing realistic capstone projects in conjunction with industry," *SIGITE '07, Proceedings of the 8th ACM SIGITE Conference on Information Technology Education, October 18–20, 2007, Destin, Florida*: 27–31.

[8]Timothy Huang, "The game of go: an ideal environment for capstone and undergraduate research projects," *SIGCSE'03: Proceedings of the 34th SIGCSE Technical Symposium on Computer Science Education, February 19–23, 2003, Reno, NV*: 84–88.

[9]Paul M. Leidig, Roger Ferguson, and Jonathan Leidig, "The use of community-based non-profit organizations in information system capstone projects," *ITICSE'06: Proceedings of the 11th annual SIGCSE Conference on Innovative and Technology in Computer Science Education, June 26–28, 2006, Bolonga, Italy*: 148–152.

[10]Roy J. Daigle and Michael V. Doran, "Facilitating Bloom's Level One through Active Learning and Collaboration," *Journal of Information Systems Education* 9, no. 3, (Winter 1998): 3–6.

[11]Michael V. Doran, Roy J. Daigle, and Robert A. Robertson, "Beyond the Classroom: Mentoring in the CIS Academic Community," *Journal of Information Systems Education*, 9, no. 3 (Winter 1998): 15–18.

SECTION V:

INTERDISCIPLINARY APPROACHES IN HONORS SCIENCE CURRICULA

Chapter 15

INTERDISCIPLINARY SCIENCE CURRICULA IN HONORS

DAIL W. MULLINS, JR.

Introduction

The University of Alabama at Birmingham (UAB), like most four-year institutions, requires all undergraduate students to satisfy a set of general studies or core curriculum requirements. According to the university's most recent catalog of undergraduate programs, these core academic requirements serve two essential purposes: (1) to provide students with an "intellectual foundation for the focused and detailed academic work that they are expected to perform" in their major fields of study; and (2) to "provide a wide exposure to ideas, perspectives, issues, and knowledge that lie beyond the narrow parameters of any individual major" and to enable "students to gain perspective on the complexity, diversity, and the beauty of the world we all inhabit."[1] Not unlike the core curricula at many, if not most, colleges and universities, the major curricular areas of the UAB Core include: written composition (six semester hours); humanities and the fine arts (twelve semester hours); natural sciences and mathematics (eleven semester hours); and history, social, and behavioral sciences (twelve semester hours).

Since its inception in 1983, the University Honors Program has provided an educational experience that satisfies these core curriculum requirements with an individualized and interdisciplinary course of study. The course of study is individualized each year because the students choose from a unique array of special three-semester-hour seminars taught by faculty from a wide variety of disciplines and professions. It is interdisciplinary because students are also required to select from among an ongoing series of nine-semester-hour interdisciplinary courses that bring together in one classroom five to six faculty from as many disciplines who address a single topic or theme from each of their respective fields. One such course is taught yearly, in the fall semester, and no course is ever repeated.

Students in the honors program satisfy the university's core by taking thirty-three semester hours of honors coursework, and, depending on a placement exam, zero to six semester hours of math and computer skills within appropriate departments outside the honors environment. The following options are available for the honors coursework, depending on an individual student's interests, time constraints, and requirements in a specific major:

- two nine-semester-hour fall-term interdisciplinary courses and five three-semester-hour honors seminars (only two of which can be related to the student's major or minor);
- two nine-semester-hour fall-term interdisciplinary courses, two three-semester-hour honors seminars unrelated to the student's major or minor, and up to nine semester hours of honors coursework within the student's major;[2] or
- three nine-semester-hour interdisciplinary honors courses and two three-semester-hour honors seminars.

It should be emphasized that the nine-semester-hour fall-term offerings are true interdisciplinary (i.e., *multi*-disciplinary) ventures, not courses taught by several faculty from a single academic department, school, or college. For example, one such course offered was "Restructuring Old Age: Perspectives on Aging" and involved faculty members from psychology, English, general science, sociology, business, and biology; another was titled "Five Immoral Acts: Lying, Stealing, Blaspheming, Killing and Fornicating" and was taught by faculty members from the departments of anthropology, philosophy, epidemiology, and English with a visiting professor of theology. Each interdisciplinary course also relies on frequent guest speakers from the community and other academic departments. Occasional class sessions are given over to open discussion of issues raised during the course, and a number of extracurricular activities, such as an evening film series or field trips, are included, which may or may not have required attendance. Unlike many such interdisciplinary ventures, moreover, the faculty participating in the interdisciplinary courses are required to attend all lectures and class discussions and to participate in at least some of the extracurricular workload if at all possible.

Interdisciplinary Courses and the UAB Core Curriculum

The UAB core curriculum's natural science and mathematics requirement stipulates that graduates, through an emphasis on the scientific method and an application of quantitative and inductive reasoning, "will understand the scientific process and the influence of science and technology on society."[1] As indicated above, this curricular goal is satisfied by students taking at least eight semester hours in the natural sciences (i.e., two courses, each with an associated laboratory experience) and at least three semester hours in mathematics at the pre-calculus-algebra level (when required). A brief, informal survey of general studies or core curriculum requirements at a variety of state and private educational institutions around the country reveals considerable similarity in these offerings, including those in mathematics and the natural sciences. Most colleges and universities require two or three introductory science courses, at least one or two of which must have an associated laboratory experience. Some schools—but not all—require students to choose courses from at least two different natural science fields.

The author has previously discussed his blanket dissatisfaction with these commonplace curricular programs, arguing that the natural science requirements at most four-year institutions cannot possibly rectify the failings of elementary and secondary schools in these disciplines.[3] In their book *Science Matters: Achieving Scientific Literacy*, Robert Hazen and James Trefil state: "Every university in the country has the same dirty little secret; we are all turning out scientific illiterates, students incapable of understanding many of the important newspaper items published on the very day of their graduation."[4] Thus, the major task facing the nascent honors program was to explore ways in which this situation might be ameliorated through the unique format of UAB's largely interdisciplinary curriculum. As outlined in two previous publications in the *National Honors Report,*[5] there were several issues and concerns to be addressed at the outset.

First, the ongoing laboratory or field-based research programs of many faculty in the natural sciences often preclude their being recruited for the time commitment required of interdisciplinary courses—currently nine contact hours per week, as well as conferences with individual students, course readings, and extracurricular events related to the course—even though the honors program budget, starting about a decade ago, allowed a $2,500 release-time honorarium for all visiting interdisciplinary faculty. This ongoing problem has been handled fairly successfully by relying on the generosity and goodwill of individual science faculty members, adjunct faculty in the sciences, and a few retired members of the faculty. Until the author retired, three full-time honors program faculty members/administrators—the director (English), associate director (biochemistry and general science), and assistant director (English)—taught in the fall interdisciplinary course each year.

Second, the lack of available laboratory facilities within the program's infrastructure presented another challenge that obviously had to be addressed in some fashion. While the author has never seen the value of requiring students, especially non-science majors, to spend time in an instructional lab setting carrying out cookbook demonstrations of simple biological, chemical, or physical principles, neither was it feasible that students be allowed to avoid altogether both the excitement and frustrations of an experimental setting of some kind. The best way to understand the scientific method is to employ it to solve a true problem rather than to duplicate recipes. The honors program solved this problem by dividing the approximately one hundred students in each interdisciplinary class into about twenty groups of three to six students each and assigning each group a research project to be completed on their own time—and with their own resources—during the fall term.[6] Thanks to the Internet, non-specialty journals that cater to amateur scientists, and material provided by several scientific professional organizations, developing twenty or more interesting and often thought-provoking research projects that challenged the students and yet were feasible within the time frame of the course was not difficult. The main difficulty, which was not overcome in all cases, was devising that many projects of approximately equivalent difficulty. In cases where this equivalency was not possible, the instructors adjusted their grading. The students presented the results of these various research projects as poster displays on the last day of class.

Finally, the cumulative nature of science courses, especially their unique dependence on a foundation of specialized terms and concepts, was difficult to fit comfortably into a true multi-disciplinary format since many of the class periods were dedicated to other, albeit related, topics such as literature, art, philosophy, and even theology.[7] It was decided instead that instructors would strive to achieve some measure of what Hazen and Trefil refer to as "science literacy"—the facts, vocabulary, concepts, history, and philosophy of science that constitute the knowledge people need to understand public issues and to participate in political discourse as opposed to the more specialized knowledge of the experts. To be sure, a large majority of the students enrolled in the honors program are science majors—many of them pre-meds—who will one day be doing science as opposed to simply using science to understand the world around them. But what these students might pick up in the way of philosophical, historical, or literary contexts of their more formal scientific training can only be viewed as beneficial.

This approach to college-level science education, especially for non-science majors, has received support from the work of Jon Miller, head of Northwestern University's International Center for the Advancement of Scientific Literacy. Miller's research during the past two decades has provided strong survey evidence that science literacy courses for non-science university students have made a surprising difference in the nation's overall level of scientific literacy. Like Hazen and Trefil, Miller defines "science literacy" as a mixture of basic science concepts plus an understanding of the nature and process of scientific inquiry, including the ability to discriminate between "scientific sense and pseudoscientific nonsense"; in short, students would demonstrate a level of knowledge required to read and comprehend the science section of a major newspaper.[8] Virtually all of Miller's statistical indicators give significant weight to science literacy courses in facilitating the development of these characteristics in the non-science public.

Table I is a list of all the science-focused fall-term interdisciplinary courses that have been taught in the UAB Honors Program since 1984 as well as the academic disciplines that were incorporated into each course. (Note that the disciplines of guest lecturers or seminar speakers are not listed.) Prior to 1996—the year when the Alabama Articulation and General Studies Committee adopted a statewide general studies curriculum at all public colleges and universities in the state, and the university went onto a true semester system instead of a quarter system—students in the honors program were required to take three fall-term interdisciplinary courses and three three-semester-hour honors seminars. The new system necessitated a reshuffling of the schedule to reflect the description of the program requirements given earlier. Thus, the honors program began offering a predominantly science-focused course every other year with intervening courses devoted primarily to the social and behavioral sciences or the arts and humanities. It is important to stress that even these latter courses always contained scientific topics just as the science courses incorporated material from the social sciences, literature, and the arts. Below are descriptions of two of these science-oriented courses.

Fall 1993—The Mythology of Western Scientific Materialism

The last course taught in the original format of the program, in 1993, was titled "The Mythology of Western Scientific Materialism: The Evolutionary Epic." This title was derived from the author's interest in the ideas and writings of E. O. Wilson, whose contention is that scientific materialism is not inappropriately viewed as a mythological narrative that deals with existential meaning and the so-called "human experience" through an explanatory format.[9] "By 'mythology,' of course, Wilson means simply to refer to any grand narrative by which we . . . attempt to explain ourselves and our place in the scheme of things."[10] Wilson argues that the explanatory format of scientific materialism is equal to—if not now superior because of its immense predictive power—both religious and socioeconomic (e.g., Marxist) mythologies. Wilson referred to this scientific mythological narrative as the "Evolutionary Epic." That this view could occasionally be shown to cause scientific and religious mythological narratives to be in genuine conflict with one another was, not surprisingly, unnerving to some students and prompted the instructors to incorporate a visiting theologian in all future science-based courses.

Table II gives a general overview of the major scientific content of the 1993 course. Virtually all lecture and classroom topics devoted to philosophy and English have been omitted from this list despite the fact that they provided a strong intellectual matrix for many of the students, especially the arts and humanities majors. As science teachers will recognize, this course, except for the earth science section, reversed the traditional sequence of science subject matter (i.e., biology→chemistry→physics) as it is traditionally presented in American secondary and post-secondary educational venues. While perhaps impractical in high school or college because of the mathematical ill-preparedness of most students, UAB instructors believed that the more logical progression of the disciplines presented in the course could be accommodated because of its less quantitative, interdisciplinary approach.

Eight texts were assigned for the course, including: *Frankenstein* by Mary Shelley; *Jurassic Park* by Michael Crichton; *Perfect Symmetry: The Search for the Beginning of Time* by Heinz Pagels; *Science Matters: Achieving Scientific Literacy* by Robert Hazen and James Trefil; *Ice Ages: Solving the Mystery* by John and Katherine Imbrie; *Elements of General and Biological Chemistry* by John Holum; *The Cartoon Guide to Physics* by Larry Gonick and Art Huffman; and *Origins Reconsidered* by Richard Leakey. In addition, students were required to purchase a book of photocopied articles and essays that contained supplementary readings for the various lectures. During the course, students were given individual written assignments in each of the following disciplines: English, physics/astrophysics, philosophy, geology, and biology. Each assignment had a specific due date, and these were scattered throughout the term.

As mentioned previously, all students in the course were divided into about twenty groups of three to six students each and assigned research projects to be completed on their own time and with their own resources. On the first day of class, each group was given a detailed handout that outlined the purpose and rationale of their project and described their project requirements, including: (1) a research log; (2) two interim progress reports; (3) the final project report; and (4) the poster session display. In addition, each group was given a one- to three-page description of their assigned research activity, including a list of starter references and/or the name of a contact person for outside help. Table III lists the 1993 Research Projects.

Fall 2000—The Environment: Earth, Air, Fire, and Water

This interdisciplinary course on the topic of the environment was one of the most ambitious attempted. Table IV is an overview of the environmental course curriculum and shows the major scientific topics covered in the almost ten-week-long term. Not shown are some of the contributions in the arts, humanities, and social sciences as well as evening public lectures and films included.

Eight texts were assigned for the course: *Vital Signs 2000: The Environmental Trends That Are Shaping Our Future* by L. Brown, M. Renner, and B. Halweil; *Heart of Darkness* by Joseph Conrad; *Global Warming: The Complete Briefing* by John Houghton; *The Storyteller* by Mario Vargas Llosa; *Environmental Science: Systems and Solutions* by M. L. McKinney and R. M. Schoch; *Ishmael* by Daniel Quinn; *Wind, Sand and Stars* by Antoine de Saint Exupery; and *The Temple of My Familiar* by Alice Walker. The major term paper for the course was a literary analysis treating any two, or all three, of the following: *Ishmael, Heart of Darkness*, and *The Storyteller*. As with all of the program's interdisciplinary courses, each student was also required to purchase a bound volume of supplementary readings.

Extra funds made available for the course allowed the program to contract with five full-time and part-time faculty in the fields of chemistry, environmental science, environmental engineering, urban affairs, and theology, thus bringing the total number of full-time instructors to eight. This extended the approach beyond a simple treatment of environmental science to include political, engineering, aesthetic, and theological dimensions of the topic. Moreover, thirteen individuals from both the public and private sectors were invited to lead class discussions on the political, social, economic, and racial dimensions of environmental policies. Environmental science is not without its controversies, and these topics allowed the class to explore some of these controversies from a variety of perspectives.

In addition, all but a few members of the entire class, about ninety students, participated in a week-long stay at the Dauphin Island Sea Lab, the state of Alabama's Marine Science Institution just off the coast of Mobile, Alabama.[11] This proved to be one of the more interesting, profitable, and enlightening components of the course. In addition to a dramatic change of environment from the classroom to a barrier island in the Gulf of Mexico, the students got to spend a week with working research scientists, in the field, trawling for biological samples and examining them in a laboratory setting. It was also interesting and educational, both for the students and the faculty, to see the students struggle with a real disconnect between their professed reverence and concern for the "out-of-doors" while within the safe confines of the classroom and their immediate need upon arrival on the island for the familiar comforts of air conditioning, electrical outlets for their grooming and entertainment devices, ice, food, and drinks.

Finally, much more sophisticated and elaborate research and engineering group projects were developed. In cooperation with UAB's School of Education, which had established one of several Professional Development Sites at the Richard Arrington, Jr. Middle School in Birmingham, the honors program agreed to assist the school in the design, construction, and long-term maintenance of an outdoor environmental education center on the school's grounds. The initial planning and development phase of this project, termed "Urban Oasis," was coordinated with the fall 2000 course as indicated in the list of research projects (Table V). Each research group of UAB Honors Program students was also responsible for involving a small cadre, four to six, of Arrington Middle School students in as many of the group's activities on the Arrington campus as possible. In addition to the group research projects, the students in the honors course were also required to maintain a month-long inventory of their water usage, energy usage, and solid waste generation.

Science Literacy and Interdisciplinary Science Courses

In *Science Matters: Achieving Scientific Literacy*, Hazen and Trefil contend that there are at least three strong arguments for the teaching and acquisition of scientific literacy: (1) the argument from civics; (2) the argument from aesthetics; and (3) the argument from intellectual coherence.

The argument from civics is the most persistently voiced by professional scientific societies, governmental science agencies, and the educational establishment and asserts that a national discussion of the many problems facing society and, indeed, the entire planet now demands at the very least a rudimentary knowledge of scientific and technological matters. "The threats to our system from a scientifically illiterate electorate are many," write Hazen and Trefil, "ranging from the danger of political demagoguery to the decay of the entire democratic process as vital decisions that effect everyone have to be made by an educated (but probably unelected) elite."[12] Alas, although Jon Miller's data have indicated increasing scientific literacy among the American public over the previous decade, these levels are still less than twenty percent[13] and very much lower, three to five percent, than among European, Canadian, and Japanese adults.[14]

The argument from aesthetics is similar to that made in support of a liberal arts education in general and contends that "the scientifically illiterate person has been cut off from an enriching part of life, just as surely as a person who cannot read."[15] Whereas the argument from civics tries to make the case that science is too politically important today to be slighted in the curriculum, I contend that the argument from aesthetics suggests that it is also simply too fascinating not to be made an integral part of one's education.

As noted in a previous publication,[16] philosophical and theological issues make their most conspicuous appearance as part of the argument from intellectual coherence. Hazen and Trefil write in *Science Matters*:

> It has become a commonplace to note that scientific findings often play a crucial role in setting the intellectual climate of an era. Copernicus's discovery of the heliocentric universe played an important role in sweeping away the old thinking of the Middle Ages and ushering in the Age of Enlightenment. Darwin's discovery of the principle of natural selection made the world seem less planned, less directed than it had been before; and in this century the work of Freud and the development of quantum mechanics have made it seem (at least superficially) less rational. In all of these cases, the general intellectual tenor of the times—what the Germans call the *Zeitgeist*—was influenced by developments in science. How, the argument goes, can anyone hope to appreciate the deep underlying

threads of intellectual life in his or her own time without understanding the science that goes with it?

If one examines the various science-focused interdisciplinary courses that have been offered during the past twenty years by the University Honors Program at UAB (Table I), it should be apparent that broad, over-arching themes—origins, nature-nurture, the environment, and the evolutionary epic—were employed more often than not in an effort to address at least the arguments from aesthetics and intellectual coherence, perhaps with the hope that a "scientifically literate electorate" might somehow emerge from this mix. The author's view[17] is that many people, and perhaps especially those students who may have come to dislike science because of the often sterile quality of secondary and post-secondary introductory science curricula, nevertheless have an almost innate fascination for what Victor Weisskopf termed the "cosmic sciences," those that deal with some of humankind's greatest questions and which, because of this, necessarily impinge on philosophical, theological, and even eschatological matters.[18]

There is precedent for a new and different approach to science education that takes advantage of the fascination most people have for the so-called "cosmic sciences." The American Association for the Advancement of Science was perhaps at the forefront of such curricular redesign efforts with the publication of *Project 2061: Science for All Americans*, in 1989, and *The Liberal Art of Science*, in 1990. The latter document contains a lengthy set of appendices that give detailed course descriptions of various innovative curricula at colleges and universities around the country.[19]

Jill Tartar and her colleagues at the SETI (Search for Extraterrestrial Intelligence) Institute in Mountain View, California, together with faculty and scientists from NASA's Jet Propulsion Lab (JPL), Evergreen State College, the Lawrence Hall of Science, the Orion School, and San Francisco State University, have developed a remarkable and innovative elementary and middle-school science curriculum (grades three through nine) that focuses on life on earth and the possible existence of life elsewhere in the universe.[20] While perhaps not of great interest to most post-secondary science faculty, it should be noted that the fundamental underlying principle of this curriculum was used to develop a series of three-hour honors seminars on the topic of SETI in the UAB Honors Program, which proved to be quite popular with students.

All of these issues and concerns underscore my deeply held conviction that many honors programs, because of their often broad interdisciplinary curricular mandates and flexibilities, have a unique opportunity to address the natural sciences in ways that are not often possible in departments of science. By interweaving the facts and principles of science with larger issues and themes of interest and importance to students, honors programs can impart something to both science and non-science majors that is often lacking or hidden in more formal science courses: larger meaning and purpose.

Table I

Science-Based Interdisciplinary Courses (1984–2008)

1984 The Cosmic Quest: Perspectives on Determinism and Free Will
History, Psychology, English, Biochemistry

1987 Mysteries of Mind, Brain and Humanity
Linguistics, English, General Science, Psychology, Philosophy, Biology

1990 The Environment: Earth in Our Shadow
Theology, Biology, General Science, Urban Affairs, English, Environmental Engineering

1993 The Mythology of Western Scientific Materialism: The Evolutionary Epic
Physics, Biology, Philosophy, English, General Science, Geology

1996 Science and Religion on a Pale Blue Dot
Theology, Chemistry, English, Psychology, General Science

1998 Galileo, Newton, Darwin and Einstein
Theology, Science History, English, Art History, General Science

2000 The Environment: Earth, Air, Fire and Water
Chemistry, Environmental Science, English, Theology, Literature, Environmental Engineering, Urban Affairs, General Science

2002 Origins
English, Literature, Biochemistry, Geology, Theology, Science Education

2004 The Nature-Nurture Controversy
Psychology, Biology, Linguistics, Literature, Theology

2006 Minds and Realities
Psychiatry, Art & Art History, Psychology, English, Literature, Urban Affairs

2008 The Anatomy of Desire
Art & Art History, Literature, Psychology, Economics, Cognitive Science, English, Urban Affairs

Table II

The Mythology of Western Scientific Materialism (1993)

Introduction (1 week)

- An Overview of Mythological Narratives, Religion and the Evolutionary Epic
- Science Illiteracy and the Science Education Crisis
- Mary Shelley's *Frankenstein* and Michael Crichton's *Jurassic Park*
- The Origin and Evolution of Science and the Scientific Method

In the Beginning (3 weeks)

- Creation Mythologies
- The Large-Scale Structure of the Universe
- The Origin, Evolution and Fate of the Universe
- The Motion of Waves
- Light and the Electromagnetic Spectrum
- Stars and Galaxies
- *Eureka:* the Cosmology of Edgar Allan Poe
- Atomic Theory and the Periodic Table
- The Subatomic Structure of Matter
- The Conservation of Momentum
- The Calculus
- The Conservation of Matter and Energy
- 1895–1925: Thirty Years that Shook Physics
- Albert Einstein and the Theory of Relativity
- Fundamentals of Quantum Theory
- The Copernican Revolution

Terra Firma (2 weeks)

- The Origin of the Earth and Solar System
- The Grand Tour
- The Earth Inside and Out: Igneous, Sedimentary, and Metamorphic Rocks
- The Age of the Earth

- Continental Drift and Plate Tectonics
- Earthquakes and Volcanoes
- Meteorology
- Climatology

A Small, Warm Pond . . . (4 weeks)

- Chemical Bonding
- Stoichiometry and the Concept of the Mole
- Chemical Reactions
- Acids, Bases and Salts: All About pH
- The Chemistry of Carbon
- The Origin of Life on Earth
- The Living Cell
- Charles Darwin: The Man, His Time, and His Theory
- The Evolution of Life on Earth
- Biological Taxonomy
- Energy and Food Chains
- Poetry, Science, and Inter-connectedness
- Mendelian Genetics
- 1900–1953: The Half-Century that Shook Biology
- DNA, RNA and the Central Dogma of Molecular Biology
- The KT Event: The Return of Catastrophism
- The Evolution of the Human Species

Table III

Group Research Projects (1993)

- Construction and Calibration of a Moondial
- Survey of Heritable Traits among Students in the Honors Program and Their Relatives
- Construction of a 2-Dimensional SETI Message Using Only Binary Digits
- Zoo Observations of Living Primate Behavior and Morphology
- Effect of Acid Precipitation on the Germination and Growth of Plants

- Effects of Cigarettes and Physical Exertion on Heart Rate and Blood Pressure
- The Honors House Graffiti Wall: an Anthropological Study
- Physiological Responses to Viewing Violence
- A Statistical Test of Astrology
- Cell-Cell Communication and Interaction
- The Efficacy of Various Brands of Paper Towels: Absorbency and Wet Strength
- Effect of Lecithin on Thermal Proteinoid Microsphere Formation in Artificial Seawater
- Survey of Easily Obtainable Acid-Base Indicators for Use in the Classroom
- Effects of Touch, Wind, and Mode of Watering on Plant Growth and Size
- Efficacy of Activated Carbon Filters in Removing Organic Contaminants from Water
- Effect of UV Radiation on the Stability of Humic Material
- Asteroid Deflection Simulation
- Saliva pH, Chewing Gum and Dental Caries
- Effect of Electromagnetic Fields on Plant Growth and Fruit Production
- Effect of UV Light on the Germination of Seeds
- The Fertility of Various Compost Types
- Can Microwave Radiation Be Used to Inhibit Microbial Growth?
- Fibonacci's Sequence, the Golden Rectangle, and Human Psychology
- The Effect of Magnetic Fields on the Embryonic Development of *Drosophila melanogaster*

Table IV

The Environment: Earth, Air, Fire, and Water (2000)

Part I—Overview (1 week)

- Water, Air, Earth, and Fire
- Ecocultures and Ethnoconflicts

- Myth of the Natural Man
- The Drake Equation: Some Thoughts on “L”
- A Sparkling Blue and White Jewel

Part II—Dauphin Island, Alabama: a Microcosm (1 week)

- Coastal Geomorphology
- Coastal Ecology
- “Island as Text” Explorations
- Biological Overview of Dauphin Island
- Political and Cultural Overview of Dauphin Island
- Alabama Coastal Area Management Plan
- Coastal Water Resources

Part III—The Driving Forces (1 week)

- Eden: How Did We Get It?
- The Peopling of the Earth
- Creation Myths and Their Environmental Implications
- Sun and Sky: How the Atmosphere Works
- Why Climates Change

Part IV—The Elements: Fire (1 week)

- Household Energy and Local Politics
- Energy: What is It? Modeling Its Impact on Climate
- Traditional Energy Resources: How Much Do We Have Left?
- The Nuclear Option
- Alternative Energy Resources

Part V—The Elements: Air (1 week)

- Ozone Good and Bad
- The Pollution Cycle and Risk Assessment
- Local Trends and Issues in Air Pollution

Part VI—The Elements: Water (1 week)

- Water: Where Does It Come From and Where Does It Go
- Water Wars: Local and Global
- Field Activity: Water Sampling

Part VII—The Elements: Earth (1 week)

- Land and Water Interactions
- The Make-Up of the Earth: The Periodic Table
- Geological Processes that Shape the Earth's Surface
- The Great Extinctions: Past, Present, and Future
- Waste Disposal

Part VIII—The Local Picture, Big Picture, and Really Big Picture (2 weeks)

- The Politics of the Environment, Alabama Style
- Alabama in the Late 21st Century: Will We Make It?
- Is Religion Hazardous or Helpful to Nature?
- International Environmental Disasters
- The Spirituality of Sacred Space & the Ambivalence of Classical Science

Table V

Group Research Projects (2000)

- Design and Construction of a Keyed Nature Trail—Phase I (Brownfield Area, Arrington Middle School)
- Design and Construction of a Keyed Nature Trail—Phase II (Drainage Creek Area, Arrington Middle School)
- Research on the Behavior of Bats and Construction of a Bat Habitat
- Investigation of the Structure, Chemical Nature, and Infiltration Qualities of Soil Surrounding the Arrington Middle School
- The Modification of Soils Surrounding the Arrington Middle School
- Design and Construction of a Composting Facility on the Arrington Middle School Grounds
- Design and Construction of Demonstration Wildflower Gardens as Wildlife Attractants on the Arrington Middle School Property
- Design and Construction of a Recycling Center Drop-Off Point at Arrington Middle School
- A Thorough Evaluation of the Watershed Area Surrounding the Arrington Middle School Property

- A Watershed Modeling Project, Including an Analysis of the Quality and Quantity of Water Runoff Conditions at the Arrington Middle School
- Design and Construction of a Computerized Rooftop Weather Monitoring Station at the Arrington Middle School
- Construction of a 30' x 14' x 8' Greenhouse at the Arrington Middle School
- Major Stream Survey, Analysis of Stream Bank Stability, and Habitat Survey of the Neighborhood Surrounding Arrington Middle School
- Analysis of the School and Neighborhood Water Supply, Including Detection of Possible Envirotoxicants (Pb, PCBs, etc.) at Arrington Middle School

Bibliography

American Association for the Advancement of Science. *The Liberal Art of Science.* Washington, D.C.: AAAS, 1990.

—. *Project 2061: Science for All Americans.* Washington, D.C.: AAAS, 1989.

Hazen, Robert, and James Trefil. *Science Matters: Achieving Scientific Literacy.* New York: Anchor Books, 1991.

Miller, Jon D. "The Development of Civic Scientific Literacy in the United States." In *Science, Technology and Society: A Sourcebook on Research and Practice.* David D. Kumar and Daryl Chubin, eds. New York: Kluwer Academic, 2000.

—. "The Five Percent Problem." *American Scientist* 76, no .2 (1988): iv.

—. "Scientific Literacy: A Conceptual and Empirical Review." *Daedalus* 112, no. 2 (1983): 29.

Miller, Jon D., Raphael Pardo, and Fujio Niwa. *Public Perceptions of Science and Technology: A Comparative Study of the European Union, the United States, Japan, and Canada.* Madrid: BBV Foundation, 1997.

Mullins, Jr., Dail W. "The Science Education Crisis and Existential Apprehension." *Forum for Honors* 21, no. 3 (1993): 18.

—. "The Science Literary Crisis, Philosophical Issues, and the Origin Sciences." *Origins of Life and Evolution of Biospheres* 25, no. 5 (1995): 495–510.

—. "A Wing and a Prayer: Trying to Reinvent Undergraduate Science Education with an Honors Program Experiment (I)." *National Honors Report* 15, no. 3 (Fall 1994): 18–23.

—. "A Wing and a Prayer: Trying to Reinvent Undergraduate Science Education with an Honors Program Experiment (II)." *National Honors Report* 15, no. 4 (Winter 1995): 15–20.

Tartar, Jill. Personal communication with the author. 1993.

University of Alabama at Birmingham. Undergraduate Catalog, 2004–2006.

Weisskopf, V.F. "Endangered Support of Basic Science." *Scientific American* 207, no. 5 (1994): 128.

Wilson, E.O. *On Human Nature.* Cambridge: Harvard University Press, 1978.

Notes

[1]University of Alabama at Birmingham, Undergraduate Catalog, 2009–2010.

[2]In addition to four campus-wide honors programs (the University Honors Program, the Experiential Learning Scholars Program, the Global and Community Leadership Honors Program, and the Science and Technology Honors Program), UAB houses twenty-two school and departmental honors programs that offer honors coursework in specific academic fields such as chemistry, anthropology, nursing, and education.

[3]Dail W. Mullins, Jr., "The Science Literacy Crisis, Philosophical Issues, and the Origin Sciences," *Origins of Life and Evolution of Biospheres* 25 no. 5 (1995): 495–510.

[4]Robert Hazen and James Trefil, *Science Matters: Achieving Scientific Literacy* (New York: Anchor Books, 1991).

[5]Dail W. Mullins, Jr., "A Wing and a Prayer: Trying to Reinvent Undergraduate Science Education with an Honors Program Experiment (I)," *National Honors Report* 15, no. 3 (Fall 1994): 18–23; Dail W. Mullins, Jr., "A Wing and a Prayer: Trying to Reinvent Undergraduate Science Education with an Honors Program Experiment (II)," *National Honors Report* 15, no. 4 (Winter 1995): 15–20.

[6]Students were told that any expenses greater than $25.00—the approximate cost of a new textbook—would be covered by monies from the honors program. Furthermore, a few of the projects required the purchase of expensive materials, such as a greenhouse kit or a weather station, which the students were not expected to cover.

[7]Hazen and Trefil, *Science Matters.*

[8]Jon D. Miller, "Scientific Literacy: A Conceptual and Empirical Review," *Daedalus* 112, no. 2 (1983): 2-; Jon D. Miller, "The Five Percent

Problem," *American Scientist* 76, no. 2 (1988): iv-; Jon D. Miller, "The Development of Civic Scientific Literacy in the United States," in *Science, Technology and Society: A Sourcebook on Research and Practice.* David D. Kumar and Daryl Chubin, eds. (New York: Kluwer Academic/ Plenum, 2000); Jon D. Miller, Raphael Pardo, and Fujio Niwa, *Public Perceptions of Science and Technology: A Comparative Study of the European Union, the United States, Japan, and Canada* (Madrid: BBV Foundation, 1997).

[9]E.O. Wilson, *On Human Nature* (Cambridge: Harvard University Press, 1978).

[10]Dail W. Mullins, Jr., "The Science Education Crisis and Existential Apprehension," *Forum for Honors* 21, no. 3 (1993): 18.

[11]Approximately ten students out of the one hundred enrolled in the Fall 2000 course were unable to attend the week-long Dauphin Island trip, either because of family matters, athletic commitments, conflicting course schedules, work, or illness. For these students, where possible, we arranged an alternative set of outdoor activities through the help and cooperation of a local area environmental organization, the Cahaba River Society.

[12]Hazen and Trefil, *Science Matters.*

[13]Miller, "The Development of Civic Scientific Literacy."

[14]Miller, Pardo, and Niwa, *Public Perceptions.*

[15]Hazen and Trefil, *Science Matters.*

[16]Mullins, "The Science Literary Crisis."

[17]Ibid.

[18]V. F. Weisskopf, "Endangered Support of Basic Science," *Scientific American* 207, no. 5 (1994): 128.

[19]American Association for the Advancement of Science. Project 2061: Science for All Americans (Washington, D.C.: AAAS, 1989); American Association for the Advancement of Science. The Liberal Art of Science (Washington, D.C.: AAAS, 1990).

[20]Jill Tartar. Personal communication with the author. 1993.

Chapter 16

THE SCIENCE OF HUMOR: AN INTERDISCIPLINARY HONORS COURSE

MICHAEL K. CUNDALL, JR.

Honors Interdisciplinary Science Teaching

In honors education one of the expressed and commonly accepted goals is to create a student who has a broad range of educational experience and interests. The oft-thought perspective that breadth covers only the traditional humanities or liberal arts is a rather myopic view of honors education. Educators need to accept and promote a broader interpretation that includes science education as a critical part of honors education.

Two main reasons support approaching honors education in this broader and more inclusive fashion. The first reason is that the goal of honors education is to produce people who are able to make informed decisions about a variety of topics that will confront them in their lives. With the ongoing debate about the proper place of evolution in science teaching in grade schools and the difficult decisions regarding stem cell research and the state and federal funding of such initiatives, students must be in a position to understand not only the humanistic concerns such issues raise, but also understand the basic science upon which various claims are based if they are to make informed decisions. The oft-cited culture wars have become increasingly important in national politics and policy; thus students must develop the skills to evaluate issues. The second reason that students need this sort of education is that they will have to make decisions about such research: the propriety of it and whether of not it should be funded. The skills they develop in learning about new research, concepts, and approaches will help them as they encounter more and varied scientific discoveries and theories. Much of the stem cell debate could be done away with if people understood what stem cells are and how they are obtained. Science's influence on an increasingly technological society cannot be overemphasized, and students need every opportunity to begin to understand the issues that they will confront after they matriculate.

The interdisciplinary science course detailed below, Humor: Interdisciplinary Perspectives, provides methods for educators in honors or elsewhere to create courses that give students science content that is not restricted to a single discipline. Interdisciplinary science courses offer students a chance to see how various disciplines, from the traditional sciences to humanities, might focus upon a specific topic. Such interaction can lead to new research that is a direct result of collaborative work and may suggest how new disciplines might arise from such interaction. The recent rise of cognitive science and neuroscience departments in academia illustrates how collaborative effort bears fruit. A further goal of the course is not simply to introduce the students to the findings and discoveries of the disciplines but to also give the students a substantial insight into the methods the disciplines employ in the development of their research programs.

Such courses provide a number of immediate benefits. Interdisciplinary science courses give students in honors an avenue by which they can supplement their major or minor course of studies while meeting their honors course requirements. These courses can also provide students with opportunities to develop research projects with professors on topics related to the course that could become senior thesis or capstone projects. Finally, the students can realize that the university is not simply a grouping of independent colleges and disciplines: a commonality exists across the campus and that commonality is particularly vibrant when students participate in an interdisciplinary course.

Since one of the main goals of an interdisciplinary course, especially when it is team-taught, is not simply to educate the students in the topic but also to demonstrate the way disciplines can and do interact. A team-taught course is preferable. As such, the course can be divided into units where each faculty member presents material from his or her discipline. Courses could be set up in three-, four-, or five-week segments relative to a standard fifteen-week semester cycle. The first lectures of each segment would introduce the students to the topic and the disciplines used to approach it, such as Introduction to Philosophy of Mind or Biological Perspectives on the Mind. These introductory lectures would be followed by more in-depth lectures, lab sessions if feasible and relevant, and capped with a summarizing lecture that brings the research and information into its place relative to the broader course topic. The final presentation should provide a segue into the next section of the course, perhaps highlighting questions and issues that one discipline found difficult to explain that the subsequent discipline might be better suited to investigate. Further, faculty should constantly remind the students how the minutiae of the discipline directly relate to the overall course topic and how findings in one area might relate to issues in another. Invited lecturers from various disciplines or colloquia sponsored by other departments across the university should supplement the lectures.

The structure of interdisciplinary course lectures should highlight and explore the current state of the science in certain relevant disciplines and reserve time for the students to attend a lab. This latter component allows them to gain firsthand experience of research methodology. A lab component adds depth to the course content relative to a specific discipline. This facet of science education is important because students often learn certain facts without paying much attention to the methods used to generate these facts. Many educators often lament this situation. In addition, such depth might allow the course to satisfy degree requirements within a science discipline, thereby allowing the honors course to serve a broad range of students.

Obviously, if one person teaches the interdisciplinary course, then that individual would present the general views of each discipline and coordinate course lectures from members of other departments to add depth about specific topics or disciplines If the course is team taught, then members typically develop their own sections and then coordinate their subjects with other members of the team as they prepare the course. Having multiple instructors is much more in the spirit of interdisciplinary work and allows the students to acquire a more accurate and direct sense of the diversity of work occurring at the university overall. Not only would students benefit from such interaction, the primary instructors might find new avenues of research that would increase the interdisciplinary nature of the campus and lead to collaborative research projects. These enterprises might use the students who were in the course to develop the research or generate projects for students to pursue.

Because faculty design these interdisciplinary courses around topics rather than disciplines, they must give the students some method of understanding the topic more generally, an avenue into the general topic in such a way that they are introduced to the issues that the class will address. The wide variety of popular science writing texts currently available on a range of topics can provide students and faculty alike a common introductory ground while leaving the more discipline-specific issues to be addressed later as the course progresses.

The idea behind using popular science texts as a base or supplement for any given course topic is that they provide the students with sources that differ from the typical textbooks or readers that students might find in a traditional course. The content style of popular science writers can often inspire generalist readers to learn more about a particular topic. Thus, these readily digestible tracts can serve as springboards into more detailed, discipline-specific subject matter.

One benefit of using popular texts is that the students might actually retain the book after they leave the class. The students might, on their own, pursue other issues raised in the text, thereby contributing to the goal that honors education should produce lifelong learners. A second benefit is that these texts are usually so fecund that the possibilities for pursuing further work in other areas of study are almost limitless. The students and professors would have a source to work from that opens many more possibilities than it closes.

The interdisciplinary science course on humor relies on a mix of traditional journal articles and more popular writings. The popular writings allow the students to wade into the research, ideas, and controversies without being beset by the many technical issues that can be found in more academic, journal-based articles. As such, the popular text will give them a reading space where their comprehension can come more easily and from which they can enter into the more technical issues without feeling lost in minutiae.

In the humor course detailed below, students explore how people perceive humor and the cues that are found in humorous situations. Psychology and philosophy are two disciplines that deal with such issues. What is laughter, how is it controlled, and what does it signal? Biology, neuroscience, and other behavioral sciences are disciplines that could address these questions. The role laughter plays in the workplace, in political activities, and in the disorders of laughter are other areas of possible interest, and these sorts of topics can draw on members of the business school, the department of political science, and the medical sciences.

Another topic for an interdisciplinary science course could be investigating the mind. This course could draw upon disciplines such as philosophy, biology, chemistry, and psychology. Yet another course could investigate the relations humans have to the environment by drawing on faculty members in biology, anthropology, chemistry, and philosophy. A final example of an interdisciplinary course is one focusing upon the evolution versus creationism/intelligent design issues by incorporating disciplines such as philosophy, biology, and physics. (See Chapter 7 of this monograph.)

Honors directors and faculty members must consider some of the difficulties of this undertaking; they must determine what background will be required of students in such a course and the possible consequences of using popular science texts. If the students in the course are generally underclassmen, then lab sections and the assumptions of professors as to what they could reasonably cover would be different than if the students were upperclassmen with some basic science requirements under their belt. Underclassmen, honors or otherwise, do not have a uniform level of science education. Further, if the students are primarily studying the humanities and would rather avoid the more technical science issues, the course content and goals might be lost on them.

The feasibility of interdisciplinary courses can be an issue. The benefit of directing these courses at upperclassmen is that they likely have a science background and are in a better position than underclassmen to work independently or under the tutelage of the professors to fill in any deficiencies in their background knowledge. Further, particular course topics will appeal to certain students because of their educational background. Even upperclassmen who take the course may lack the background knowledge of the disciplines to engage the material effectively or may not adequately recall previous course material. To correct these problems, faculty should make remedial readings and materials available to students. Even professors involved in the course might benefit from reviewing resources from other disciplines. The group teaching the course should reach a consensus about the parameters, goals, and texts.

One objection about using popular science writing texts as introductions to a topic is that these sources water down scientific findings that often distort, omit, or improperly offer as truth the findings they report. Obviously, faculty should avoid seriously flawed works, but even solid, well-written text may have errors. If there are errors in the text or sections that are contentious, then the instructors should discuss these issues with the class and submit them for further review by the students. In this way, the students can develop their critical-thinking skills and prepare themselves for the scientific and technical texts they will engage as the course progresses. The challenge of an introductory course is to ensure that the students maintain an intuitive sense of the material so that they do not lose perspective on the overarching themes because of the minutiae of specific disciplines.

Interdisciplinary Humor Course

Humor and Laughter: Interdisciplinary Perspectives involves philosophy, psychology, biology, neuroscience, medical science, literary studies, and sociology. A course on humor and laughter easily generates interest. The very idea of taking a class about what is funny is enough to lure quite a few students. The texts used in the course are *Jokes: Philosophical Thoughts on Laughing Matters* by Ted Cohen and *Laughter* by Robert Provine. A host of other supplementary readings augment the course. The class begins with an introductory lecture that sets out the overall goals of the course. The students are expected to learn about the various ways in which humor and laughter have been studied across disciplines and become familiar with the techniques and findings of these disciplines. The students give a presentation on a chapter or section of the course and on their research papers. The students are quickly disabused of the notion that this course is a place where they might practice their own particular brand of comedy or develop a sense of humor. The class will be about what researchers have uncovered relative to the phenomenon of laughter and humor and not a course centered on goofing off.

Early lectures and discussions are devoted to introducing the disciplines and aspects of humor and laughter that will be covered in the class. Once students learn that laughter and humor are not always concomitant acts, they begin to develop the analytic skills necessary to discern the various issues surrounding laughter and humor.

Divorcing laughter and humor introduces the students to an important distinction in the subject matter. Noting that laughter does not always accompany the perception of humor allows for the biological and ethological study of laughter, the mechanisms of laughter, and the diseases and disorders of laughter. Articles from biology, neuroscience, medical research, psychology, and psychiatry explore various aspects of laughter and humor. During presentations and discussions that focus on these aspects of laughter and humor, the students are encouraged to pay particular attention to the ways in which the various cases are made in the articles under review. For example, the specific case of laughter's purported health benefits is closely scrutinized. Early reports of laughter's health benefits far outstrip the data. The general folk wisdom is that laughter and humor are good for a person's health; however, no really strong evidence supports this claim, despite the many articles that claim humor and laughter are directly related to positive health. Although recent research seems supportive of the folk wisdom, the support is not without issues. Further, the health benefits described may be vague claims of just feeling healthier or simply expressing the sensation that when one laughs, one feels better. While this perception is likely true for many because a feeling of mirth is often associated with laughter and humor, just claiming people feel better does not prove they are actually healthier. Because the articles and books reviewed in this section are not exhaustive, the students have the opportunity to pursue the issues that interest them in their research papers.

The next section of the course focuses on the nature of humor by developing a theory of the humorous. This section begins with early philosophical accounts of the humorous. Students are encouraged to evaluate the validity of the arguments presented. This section of the course then leads students into empirical research that attempts to distinguish between competing theories of the humorous. The journal articles connected to these discussions develop the students' ability to analyze and critique experimental design. This psychological and philosophical research leads to the final section of the course, which focuses on the function of humor.

The readings in the final section of the course present sociological and ethological research on the function of humor. Students attempt to understand what sorts of use humor has. Is it a coping mechanism? Is humor appropriate in therapeutic settings? Is humor divisive and derogatory? What does the prevalence of one sort of humor or joke type in a culture indicate about the culture where the humor is found? Is racist and ethnic humor ethically wrong? Answering and researching these questions require an entirely different approach than doing research into the neurobiology of laughter. Hence the students can see how a topic can be looked at and treated by a wide variety of disciplines within the university. For example, while racist and ethnic jokes may be funny to some people, this supposed humor does not necessarily make this type of humor appropriate in therapy, though sometimes it may very well be.

While the above disciplines and issues relative to humor and laughter are in no way exhaustive, they provide a sense of how various disciplines can be united into a coherent course framework. This course attempts to give both depth and breadth to the students. The students are asked to pay careful attention to the claims, evidence, and arguments being made by the various authors. For instance, one researcher on laughter makes a case for distinguishing between laughter and humor.[1] Too often, Provine claims, people consider the two as interchangeable. With an impressive set of studies and statistical figures, Provine argues that humor is not any one particular thing. The students may take this issue to be settled until the psychologists raise the question about what gives humor its funniness. Ultimately the students are required to treat topics, such as the one just reviewed, in an in-depth fashion in their research papers. By writing three papers in this course, the students engage in the often difficult process of blending interesting and divergent views into a manageable presentation.

Conclusion

The goal of the course on humor and laughter is to educate students in ways that achieve both breadth and depth relative to the disciplines supporting such a course. The possibilities of materials and themes for such a course are boundless. The only restraints on such a course are the willingness of the professors to work in a collaborative spirit, the students' engagement of the material, and the material resources to maintain such a course. If the last of these conditions can be rendered unimportant, the class should provide students in honors with a course that shows them just how the variety of disciplines on a campus might intersect to develop new lines of inquiry on various topics.

Suggested Readings

Laughter: A Scientific Investigation. R. Provine, 2000, NY: Viking Press

Guns, Germs and Steel. J. Diamond, 1999, NY: Norton.

The Botany of Desire. M. Pollan, 2001, NY: Random House.

Science Truth and Democracy. P. Kitcher, NY: Oxford University Press.

The Emperor of Scent. C. Burr, NY: Random House Publishers.

Inside Jokes. M. Hurley, D. Dennett, and R. Adams, MA: The MIT Press.

The Primer of Humor Research. V. Raskin eds., NY: Mouton de Gruyter.

Bibliography

Provine, Robert R. *Laughter: A Scientific Investigation.* New York: Viking, 2000.

Note

[1]Robert R. Provine, *Laughter: A Scientific Investigation* (New York: Viking, 2000).

APPENDIX:

Sample Syllabus

Title
Historical Theories of Laughter and Humor

Instructor
Dr. Michael K. Cundall, Jr.

Texts

- *The Philosophy of Laughter*, John Morreal, Editor—Packet
- *Laughter* by Robert Provine
- *Philosophical Thoughts on Joking Matters* by Ted Cohen
- Various handouts

Goals
This course is designed to help students become aware of and conversant in issues and topics relative to the interdisciplinary study of humor. The course will cover material on humor from philosophy, psychology, biology, sociology, and other disciplines. Students will also see how a variety of disciplines can focus on and study one general topic of inquiry. Students will be asked and instructed to see the similarities.

Objectives
A student should be able to evaluate various theories of humor and see what current research into humor might have to say about these theories. They should also demonstrate the ability to synthesize new research about humor to inform theories they have studied and develop their own views on it. Students will also be able to interact and engage the material in a thoughtful and critical fashion both in class and in their writing assignments.

Course Requirements/Grading Method
There will be a number of short comprehension papers due on various readings throughout the term. There will also be 2 shorter papers that critically engage some topic or set of issues found in the class material. There will also be a final paper, which will likely be a substantial research paper, on one of the topics in the class. The topic will likely be co-opted from one of the earlier short papers. These short writing assignments and papers will comprise 90% of your final grade. The other 10% will come from class participation. In addition, students will have to give a presentation over some paper or topic in the class readings.

Classes will be discussion driven rather than lecture oriented. Students will be expected to come to class prepared to discuss the day's readings. And since this is a class about humor, witty anecdotes and some level of wit would be quite appropriate. We will find that these topics, though on the lighter side, will have quite interesting things to say about our cognitive make-up.

Attendance
You are allowed three unexcused absences. Any more than that and you ***will*** be dropped one letter grade off of your final grade. The effect is cumulative (i.e., 5 absences = 2 letter grades dropped from final grade). A final grade of B less 5 unexcused absences = D.

Tentative Readings Schedule

Weeks 1–2: The Superiority Theory—Plato, Aristotle, Cicero and Hobbes

Do we only laugh at those we deem lower than ourselves?

The Philosophy of Laughter, John Morreal

Weeks 3–6: The Relief Theory—Freud, Spencer and Bergson

Laughter and the release of physical and psychic energy.

The Philosophy of Laughter, John Morreal

Weeks 9–12: The Incongruity Theory—Kant, Hutcheson, McGhee and Kierkegaard

Why that's a knick-knack Patti Black give that frog a loan!

The Philosophy of Laughter, John Morreal & Handouts from McGhee's *Humor*

Weeks 12–13: Biological research into humor & laughter: new directions

How did laughter develop? What is its function?

Laughter by Robert Provine

Weeks 14–15: Aesthetic and emotional aspects of laughter and humor

When is it appropriate to laugh? Is humor an emotional response?

The Philosophy of Laughter, John Morreal

Philosophical Thoughts on Joking Matters by Ted Cohen

Chapter 17

AN INTERDISCIPLINARY UNDERSTANDING OF A DISEASE: PROJECT FOR AN HONORS-EMBEDDED BIOCHEMISTRY COURSE

KEVIN M. WILLIAMS

Introduction

One of the challenges of undergraduate education is helping students to see connections between disciplines. Students occasionally fail to see connections even between closely related disciplines, such as the importance of the fundamentals of chemistry to an understanding of biology at a molecular level. Even among students, however, who see connections across related science, technology, engineering, and mathematics (STEM) disciplines, there may be difficulties understanding the connections with non-science courses in the curriculum. Giving students an opportunity to consider relevant scientific topics from perspectives other than the scientific perspective is important.

Honors courses should provide opportunities for students that are unique from the traditional large lecture format. For example, small group collaborations can be used to foster teamwork and allow problems to be considered from different perspectives that may span disciplines. Unique learning experiences may provide students opportunities to present or publish work, which promote professional development and give students tangible documentation of their accomplishments. Knowledge learned in honors courses may be directly applied to real-world problems; thus, students can integrate their educational experiences with their future career choices. Such innovative opportunities can be an excellent means of engaging students within the curriculum.

A number of approaches have been utilized in chemistry and biochemistry to supplement or replace the traditional lecture format. A problem-based approach to biochemistry was described in which engaging problems were introduced with the major concepts.[1] Process-oriented guided inquiry learning (POGIL) has been utilized in several instances, including large classes, as an alternate to traditional lecture.[2] Jmol, a freely available Java-based viewer for 3-D chemical structures, has been utilized in a traditional lecture class as the basis of research projects on structure-function relationships.[3] Wikis have been utilized as the basis of problem-based assignments,[4] for online lab reporting,[5] and for student-created websites explaining mechanisms of action of molecules.[6]

Group projects can be useful strategies for helping students make connections between different disciplines. They are also good for promoting teamwork and respect for the ideas and contributions of others; however, group projects also pose unique challenges. Because assessment of individual contributions to a group project is challenging, faculty often assign the same grade to everyone in the group. As a result, students are sometimes frustrated if they feel that other group members are not contributing equally to a project, and the students may feel they have little ownership of the end product. Also, assembly of the work of several students into a coherent final form may be arduous. Students may have limited access to other group members' contributions while the project is ongoing, making the end product a compilation of individual pieces instead of a coherent and integrated effort. The assembly process may require one student to collect all of the pieces and work them into a common style and format.

A group honors project utilizing a wiki for an upper-level biochemistry course is described below. While a number of chemistry and biology majors at Western Kentucky University are enrolled in the honors college, their number was originally too small to justify a separate Honors biochemistry course each semester. Thus, the honors college has offered on three occasions an honors-embedded section of the biochemistry course in which the described project has been utilized. Five students enrolled in and completed this honors section in the fall of 2007. In the spring of 2009, ten students enrolled in the section, and thirteen students enrolled in the fall of 2009. The lectures and four non-comprehensive tests were identical for the honors and non-honors students in each semester; however, instead of a comprehensive final exam, the honors students collaborated throughout the semester on a group project. The replacement of the group project for the final exam avoided the perception that the honors assignment was extra work, yet the honors students' exposure to the core content of the course was maintained.

Assignment Overview

For this project, each group of students chooses a disease to investigate during the course of the semester. To gain a comprehensive understanding of the disease and its effects, the students must consider several perspectives. In other courses chemistry and biology majors often concentrate, for example, on only the biochemical or clinical perspectives of diseases; they may be less experienced when it comes to considering the impact on a patient or on society as a whole. Some of the potential perspectives for consideration, along with examples of how those perspectives can be used to understand representative diseases, are given below.

Barbara Gross Davis has argued that groups of four to five people generally work well for projects.[7] Groups of three would be possible but difficult for the project described here, whereas four to six students should be ideal. Group dynamics could start to be problematic above seven or eight students; thus, larger classes need multiple groups, each of which can choose a different disease. Groups of four or five students have been utilized to date.

The students are encouraged to meet weekly to discuss current progress and future plans; however, the project itself is assembled online via a wiki, allowing for asynchronous communication as well. (See below.) Initially, each student chooses a particular area of interest to investigate, and as they obtain new information, they can develop new questions. The information-gathering experience is going to be iterative. Depending on the disease that is chosen, some areas will be richer in information than others. Thus, students are cautioned against assuming that they will spend much of the semester focusing on one perspective.

Examples of Perspectives

A clinical perspective of a disease considers causes and risk factors, diagnosis, treatment options, and long-term prognosis. Some clinical information is readily available to the general public for some common diseases and conditions; for example, the National Parkinson Foundation's website has information about the diagnosis and treatment of Parkinson's disease.[8] Parkinson's disease is difficult to diagnose, and usually MRI scans are used to rule out conditions with similar symptoms. Parkinson's disease itself cannot be treated directly although the symptoms can be treated by levodopa. Connecting this type of information to the molecular level, for example, by understanding the chemistry of dopamine and considering effects on the patient and society can be a unique experience for students.

Much of the first-semester biochemistry course focuses on key molecular interactions that are important in normal or abnormal cellular function. Throughout the course students explore many diseases at the molecular level. Sickle-cell anemia, for example, is caused by a specific amino acid mutation in the oxygen transport protein hemoglobin, which aggregates in the mutant form.[9] Type 2 diabetes results when the body becomes unresponsive to the hormone insulin, which normally signals the "fed state" and leads to storage of glucose and other fuels.[10] Understanding the biochemical mechanism of a disease is important because this understanding can lead to improvements in treatment and diagnosis.

In addition to understanding the disease from a clinical and biochemical perspective, students should consider the impact of the disease on the lives of individuals. Multiple sclerosis is a good example of a disease that alters the patient's lifestyle; the majority of people who have multiple sclerosis report significant fatigue, and approximately half have cognitive dysfunction.[11] As a result, job performance may be affected, and fatigue is often a primary reason for loss of employment. In addition, a disease can affect friends and family and not just the patient; Alzheimer's disease affects elderly patients, who are often cared for by a spouse or close relative. These caregivers can experience stress, loss of intimacy, fatigue, and depression.[12]

Diseases can have a tremendous impact on society as a whole. One of the best historical examples of a disastrous social impact from a disease was the Black Death of the Middle Ages. The plague, which killed more than a quarter of the population of Europe, caused food prices to soar in Italy, led to some anti-Semitism in Germany, and altered much of the existing social structure throughout Europe. Art and literature after the plague suggested that survivors had an altered view of death.[13]

As the students gather initial information about their chosen disease from varying perspectives, they must make connections across perspectives and disciplines. Understanding, for example, that the clinical causes of the Black Death were unknown in the Middle Ages would help to explain feelings of fear or depression during the era.[14] As another example, the resistance to malaria by carriers of the sickle cell anemia gene can explain the prevalence of sickle cell anemia in those of African descent.[15] In order to make such connections, the students must communicate with one another and have access to each other's information throughout the project. Having early versions of the project available to all group members is important so that all members can modify the project easily and regularly.

Assembly of Project via a Wiki

A wiki is a website that can be both viewed and modified by multiple users. Many students and faculty members are familiar with Wikipedia, which describes itself as the "free encyclopedia that anyone can edit."[16] Users who access a wiki page will see the most recently modified version of the page; however, previous versions of the page are retained. The retention of previous versions provides a convenient way to document each user's participation in the construction of the page; it also ensures that changes are not permanent.

An obvious problem of a public wiki for a class project is that anyone with access to the Internet could not only view but also modify the website. Thus, Internet users external to the class could add or change content. Many wikis, however, can be made private, and thus only invited users, such as the group members, can view or modify the site. Of course, the wikis can be made public at the end of the semester if desirable.

Netcipia[17] was chosen for the fall 2007 and spring 2009 projects because students could establish a private wiki free of charge. While the interface was somewhat primitive, the students did not experience any major technical problems while using the wiki. A "place" created in Netcipia contained both a wiki and a blog (weblog). The blog allows participants to post messages, to which other group members can respond. Students use the blog to update other group members about ongoing work or to let one another know about interesting articles or information that has been found. By adjusting the settings, the instructor, who creates the wiki, can make the wiki available for public viewing or modification at a later date.

The Blackboard Academic Suite, which is utilized at Western Kentucky University, now has blog and wiki features available, and these were utilized in the fall 2009 semester projects. Because the students were already familiar with the Blackboard interface, implementation of the wikis was somewhat more straightforward than with Netcipia. Making the wikis available for public viewing, however, was somewhat easier for the Netcipia wikis. New site construction is no longer available on Netcipia although similar wiki-hosting sites may be available.

As students discovered new information, they were encouraged to enter the information into the wiki as soon as possible. Once the new information was added, the most recent version became immediately available to the other group members; thus, to get the most recent version, a student needed only access to the internet. All previous versions of the wiki were retained and available to all group members and the faculty member, thus documenting what information was added by each student. The versions could be compared to one another to show changes and additions at a glance, making documentation and assessment of individual contributions relatively straightforward.

Specific Implementations

Five students participated in the group project in the fall semester of 2007; all five were preparing for medical, dental, or veterinary school. The choice of disease was left to the students although cancer and AIDS were not recommended because of the magnitude of information available on those topics. The students chose Alzheimer's disease, which was an ambitious but acceptable choice; some students had friends or family members with the disease, and the topic was timely and relevant for them.

Two students began with the biochemical perspectives of the disease. A third student focused on risk factors and prevention measures. The remaining two students began by considering the effects on the patient and society. During the course of the project, the students considered other perspectives. For example, a factor affecting Alzheimer's patients and families of the patients is that a diagnosis has historically been confirmed only through autopsy and hence uncertainty exists in the diagnosis while the patient is alive. The student considering the impact on the patient and family eventually investigated novel methods that are being used for detection of the disease in living patients. One student who began by considering the biochemistry of the brain and the mechanisms of disease also considered whether lifestyle choices, such as choice of career or leisure activities involving concentration, could affect the biochemistry of the brain and hence reduce the likelihood of or impact from Alzheimer's disease. Near the end of the project, the students were communicating regularly to fill in gaps and make connections between the individual components. Since each student had access to the project's latest draft via the wiki, students could integrate ideas seamlessly.

By the end of the semester, most of the students felt that they had made a distinct contribution by compiling and comparing information from several different sources and perspectives. The consensus among the students was to make their information available to the public on the internet. Furthermore, the students considered presenting their investigations as part of the Kentucky Honors Roundtable in the spring semester, even though that activity was not a part of the grade for the course. The wiki was made public, with write privileges still restricted to the group members to preserve the integrity of the final version.

In the spring of 2009, two groups of five students each were formed. One group selected idiopathic pulmonary fibrosis, and the other group selected Crohn's disease. Because regular weekly group meetings were difficult to schedule during this semester, each group held only a few meetings. One of the groups did not post information promptly, resulting in much work for that group during the final portion of the semester. Even monitoring the progress of two different groups was difficult because of the scheduling problems. Fortunately, both groups of students completed these projects successfully.

For the fall 2009 implementation, regular group meetings were recommended but not required; some students had busy schedules that precluded convenient meeting times. Students did, however, have a strict deadline, which was approximately the midpoint of the semester, for posting substantive content into the wiki, and students were warned that they could be removed from the honors section if they did not post on schedule. The groups chose atherosclerosis, Down syndrome, and xeroderma pigmentosum for their diseases. They completed their projects in a timely manner, and the students communicated well despite the lack of regularly scheduled meeting times with the instructor.

Conclusions

Typically, a significant percentage of honors students in chemistry and biology are pre-health professional students preparing for medical, pharmacy, or other professional schools. Other honors students may be preparing for graduate studies in the biomedical area. The analysis of a disease is particularly interesting and relevant to these students as well as a number of other honors students because they or their friends and family members have had to contend with health issues. Thus the impact of these diseases resonates for many students.

Overall, the projects have had a number of successes. Several students commented that they enjoyed the projects and the requirement to consider a disease's impact from a variety of perspectives. Several of the students engaged perspectives, such as the impact on society, that were not familiar to them. For the students who focused on the molecular and cellular perspective, many of their findings connected well with topics that had been covered in the biochemistry lecture; other students had to do additional background research. For example, most of the students were unfamiliar with the anatomy of the brain, and understanding this organ was essential for the fall 2007 group that studied Alzheimer's.

Students also commented that they felt they had accomplished something that was useful by the end of the semester. Because they had focused on a disease, they felt that they had investigated a real problem and had compiled information from a number of sources. Many of the students were interested in presenting the results of their project or making the wiki information publicly available; thus, the students perceived value in the project beyond the grade.

Because it is important that group activities be critical-thinking exercises, the group should discuss the project regularly, especially as a significant amount of information is gathered. While the blog and wiki provide asynchronous communication measures, conversations in person can still be valuable to the project construction. These meetings help the students avoid the tendency to focus only on their individual piece of the puzzle. When regular meetings are impractical, however, because of the number of groups or schedule conflicts, the instructor can monitor the wikis and provide individual or group feedback to encourage appropriate progress.

The wiki implementation alleviated several problems that are normally present in group projects. Assessment of individual contributions is possible because previous versions of the wiki are retained and can be compared to discern specific additions and changes made by an individual student. Posts and comments in the blog further document each student's contributions. This documentation was both motivating and reassuring for students. One student commented that he typically disliked group projects because all group members earn the same grade even if one or two students end up doing most of the work; thus, he preferred a group project like this one in which each member's contribution could be documented.

The wiki allows all group members and the instructor to access the most recent version of the group project. This access reduces the likelihood of two or more students gathering redundant information and helps students to connect their own findings to the information that others have entered. It also ensures that a copy of the project is available at any time and from any location with Internet access; thus, the project can be viewed and edited asynchronously. The instructor can monitor the progress of a group and provide feedback via blog postings, e-mails, or group meetings.

The wiki implementation, however, did pose a few challenges. Because all previous versions of the wiki are retained, some students were hesitant to post information into the wiki that felt preliminary. One solution would be incorporating posting deadlines into courses that utilize wikis to ensure that students enter information as early as possible. Minor technological glitches also occurred; some students, for example, accidentally created a new wiki page rather than posting into the existing wiki. Another problematic issue arose, especially near the end of the semester when students were scurrying to finish the project, because students at different computers were attempting to modify the wiki page simultaneously. Overall, however, the students successfully utilized both Netcipia and Blackboard wikis to complete the projects in a timely manner.

Obviously, most students utilize the Internet as their initial source of information, and many diseases have national societies or foundations that are rich sources of information. Instructors should, of course, encourage students to research biochemical and clinical studies, but they should also urge students to explore resources beyond the written literature. When working on real-world projects like this one, students should visit hospitals, research centers, nursing homes, or other locations that may provide enriching experiences and firsthand accounts of the effects of a disease. Overall, the inclusion of the project in the biochemistry course was successful, and future biochemistry courses at Western Kentucky University will likely have an honors-embedded section with a similar project design.

Suggested Readings

Henderson, John G. *RSS for Educators: Blogs, Newsfeeds, Podcasts, and Wikis in the Classroom.* 1st ed. Eugene: International Society for Technology in Education, 2008.

Honors biochemistry website (Netcipia). Available online at <http://honorsbiochem.netcipia.net>.

Interdisciplinary Perspectives on Infectious Diseases. Available online at <http://www.hindawi.com/journals/ipid>.

Richardson, Will. *Blogs, Wikis, Podcasts, and Other Powerful Web Tools for Classrooms.* 1st ed. Thousand Oaks: Corwin Press, 2009.

Strayer, Joseph, ed. "Black Death," in *Dictionary of the Middle Ages.* New York: Charles Scribner's Sons, 1982.

Wiki (Wikipedia entry). Available online at <http://en.wikipedia.org>.

Bibliography

Alzheimer's Association Website. Available online at <http://www.alz.org>.

Bailey, Cheryl P., Vicky Minderhout, and Jennifer Loertscher. "Learning Transferable Skills in Large Lecture Halls: Implementing a POGIL Approach in Biochemistry." *Biochemistry and Molecular Biology Education* 40 (2012): 1–7.

Berg, Jeremy, John Tymoczko, and Lubert Stryer. *Biochemistry*. New York: W.H. Freeman, 2007.

Clougherty, Robert, and Mona Wells. "Use of Wikis in Chemistry Instruction for Problem-Based Learning Assignments: An Example in Instrumental Analysis." *Journal of Chemical Education* 85 (2008): 1446–1448.

Davis, Barbara Gross. *Tools for Teaching*. San Francisco: Jossey-Bass Publishers, 1993.

Dods, Richard F. "A Problem-Based Learning Design for Teaching Biochemistry." *Journal of Chemical Education* 73 (1996): 225–228.

Elliott III, Edward W., and Ana Fraiman. "Using Chem-Wiki To Increase Student Collaboration through Online Lab Reporting." *Journal of Chemical Education* 87 (2010): 54–56.

Evans, Michael J., and Jeffrey S. Moore. "A Collaborative, Wiki-Based Organic Chemistry Project Incorporating Free Chemistry Software on the Web." *Journal of Chemical Education* 88 (2011): 764–768.

National Parkinson Foundation. Available online at <http://www.parkinson.org>.

Netcipia. Available online at <http://www.netcipia.net>.

Saderholm, Matthew, and Anthony Reynolds. "Jmol-Enhanced Biochemistry Research Projects." *Journal of Chemical Education* 88 (2011): 1074–1078.

Stratmoen, Jo. "On the Job with Fatigue and Cognitive Issues." *Inside MS* (March 2006): 10–15.

Strayer, Joseph, ed. "Black Death." In *Dictionary of the Middle Ages*. New York: Charles Scribner's Sons, 1982.

Wikipedia. Available online at <http://www.wikipedia.org>.

Notes

[1]Richard F. Dods, "A Problem-Based Learning Design for Teaching

Biochemistry," *Journal of Chemical Education* 73 (1996): 225–228.

[2]Cheryl P. Bailey, Vicky Minderhout, and Jennifer Loertscher, "Learning Transferable Skills in Large Lecture Halls: Implementing a POGIL Approach in Biochemistry," *Biochemistry and Molecular Biology Education* 40 (2012): 1–7.

[3]Matthew Saderholm and Anthony Reynolds, "Jmol-Enhanced Biochemistry Research Projects," *Journal of Chemical Education* 88 (2011): 1074–1078.

[4]Robert Clougherty and Mona Wells, "Use of Wikis in Chemistry Instruction for Problem-Based Learning Assignments: An Example in Instrumental Analysis," *Journal of Chemical Education* 85 (2008): 1446–1448.

[5]Edward W. Elliott III and Ana Fraiman, "Using Chem-Wiki To Increase Student Collaboration through Online Lab Reporting," *Journal of Chemical Education* 87 (2010): 54–56.

[6]Michael J. Evans and Jeffrey S. Moore, " A Collaborative, Wiki-Based Organic Chemistry Project Incorporating Free Chemistry Software on the Web," *Journal of Chemical Education* 88 (2011): 764–768.

[7]Barbara Gross Davis, *Tools for Teaching* (San Francisco: Jossey-Bass Publishers, 1993).

[8]National Parkinson Foundation. Available online at <http://www.parkinson.org>.

[9]Jeremy Berg, John Tymoczko, and Lubert Stryer, *Biochemistry* 6th ed. (New York: W.H. Freeman and Co., 2007).

[10]Ibid.

[11]Jo Stratmoen, "On the Job with Fatigue and Cognitive Issues," *Inside MS* (March 2006): 10–15.

[12]Alzheimer's Association. Available online at <http://www.alz.org>.

[13]Joseph Strayer ed., "Black Death," in *Dictionary of the Middle Ages* (New York: Charles Scribner's Sons, 1982).

[14]Ibid.

[15]Berg, Tymoczko, and Stryer, *Biochemistry.*

[16]Wikipedia. Available online at <http://www.wikipedia.org>.

[17]Netcipia. Available online at <http://www.netcipia.net>.

SECTION VI:

THINKING LIKE A SCIENTIST: A TOOLKIT

Chapter 18

REPLACING APPEARANCE WITH REALITY: WHAT SHOULD DISTINGUISH SCIENCE IN AN HONORS PROGRAM?

LARRY J. CROCKETT

Introduction

In October 2006, a general education task force at Harvard University proposed, given the growing effect of religion in the contemporary world, that all students take a course entitled "Reason & Faith." Sharp criticism, however, quickly appeared. As reported in *Newsweek*, January 22, 2007, Harvard psychology professor Steven Pinker observed, "There is an enormous constituency of people who would hold that faith and reason are two routes to knowledge . . . it's like having a requirement in Astronomy & Astrology." In December 2006, the proposal for "Reason & Faith" was withdrawn and replaced by a less provocative title: "What It Means to Be a Human Being."

The controversy over religion at Harvard notwithstanding, honors students usually understand the impact of religion in contemporary events since they are generally well read. Even though only one college student in twenty chooses a science major in the United States, honors students choose science majors more often and appear to have a keen interest in scientific issues. These seemingly discordant trends should not be surprising. The United States, with both more Nobel prizes in science and more creationists than any other country, has long been divided with regard to the relationship between science and religion. With Ronald Reagan, who intoned on behalf of General Electric in the 1950s, "progress is our most important product," Americans often mouth an allegiance to science in general terms but balk if specific scientific claims appear to undermine traditional beliefs. In his successful 1980 campaign for the presidency, Reagan observed that evolution "is a scientific theory only."

Augsburg College had an unusual opportunity to place science in a prominent position in its honors program with a grant from the National Science Foundation in the late 1990s. The honors program not only required honors students to do more in science than other students, it encouraged the significant number of science majors in the program to include a philosophy of science course as part of their honors curriculum. Given that Augsburg has had an exceptional relationship with NASA for many years, this nuance in the curriculum is not surprising. What may be surprising is that Augsburg is a church-related institution that emphasizes faith and reason.

The purpose here is not to traverse the well-worn path of the putative warfare between science and religion. Instead, the goal is to suggest some ways that science can be given a distinctive emphasis in an honors curriculum. My perspective is that of a computer scientist and a philosopher of science, and in the sixteen years that I have directed the Augsburg College Honors Program, I found that many of my most beguiling experiences stemmed from this kind of effort. On one hand, the program challenged some outstanding students' uncritical reverence for science as an unproblematic method to truth. On the other, it rekindled in students with marginal interest in science—but considerable passion for the humanities—a fascination with scientific questions by approaching them via the history and philosophy of science.

Deconstructing the "P Word"

The *Newsweek* article cited above noted that "many are infuriated by what they see as a widespread erosion of belief in proven scientific theories, such as evolution." Predictably, many honors students are convinced that what distinguishes science from other academic enterprises is that, by virtue of its relation to evidence and perhaps its adherence to the scientific method, a scientific theory is capable, at least in principle, of being proven. The "p word," as it is called at Augsburg, is as golden a pedagogical treasure trove as the gods have ever bestowed: evocative, widely used, and surprisingly treacherous philosophically.

One objection is that scientists prove countless claims. As chronicled well by Curtis Franks (2010), in 1900 David Hilbert dreamed of a universal mathematics in which all theorems would be provable. Newton's mechanics still held sway, and many believed that all human problems would fall to a mathematicized scientific method. Hilbert was famous for saying, "We must know, we will know." But these words had scarcely fallen from his lips when Kurt Gödel dashed Hilbert's dream in 1931 by proving that it is impossible to prove all true theorems. Thus the method of proof was used to undercut the dreams of what proof can achieve. Computer scientists agreed that no formal way to determine whether an arbitrarily chosen program will halt under its own control exists. Indeed, it is generally the case that the programs that direct airplanes cannot be proven correct. The controversial Stephen Wolfram, of *Mathematica* fame, has underscored the decaying trajectory of the word "prove" as people attempt more difficult proofs. Keith Devlin has observed, "I see a parallel between the uncertainty of these proofs and developments in physics like string theory, where we're developing mathematical theories of matter that may forever remain elusive to experimental verification" (*Seed,* Aug. 31, 2012). Indeed, the traditional distinction between the formal and natural sciences is eroding with the advent of inexpensive but powerful computing machines (Chaitin, 1993).

Devlin's comment points to the fact that the problem fully encompasses the natural sciences. Since the quantum mechanical revolution in the 1920s, physicists have understood more than most scholars Richard Rorty's caution that people can never justifiably claim to be "replacing appearance with reality" (2007, 104). People do not have unmediated access to reality; instead, they must use constructs of their own devising to describe a reality lying beyond the lens of experience. Theories cannot be promoted to facts since theories are a behind-the-lens account of what cannot be observed directly. This limitative result to empirical science comes from twentieth-century philosophy of science, and I use it to awaken my students from their "dogmatic slumber," as Kant (2011, 7) put it more than two hundred years ago. Contrary to popular and some academic supposition, then, no science can *prove* any empirical claim. I put it just this directly in class, and my students are either with me or against me. In either case, they are memorably animated by the argument.

When people imagine that evidence, along with some assisting math or logic, can prove a theory true, they are guilty of the elementary fallacy of affirming the consequent. That is, while it is the case that a theory entails its evidence, no amount of evidence logically entails a specific theory. I insist that my students "do the math" (the propositional logic) in full detail, which can be done in less than an hour. Then they have it in black and white on one sheet of paper: the commonly understood logic of science that is called "confirmationism"—devise a theory, test an observable consequence of the theory via experiment, then conclude the theory is confirmed by a successful experiment—is itself demonstrably fallacious. Students, thus, have a logical proof that there can be no empirical proof. As Kosso puts it, "the observations of the world . . . are not sufficiently informative to single out the one true theory of what is going on behind the appearances" (1992, 87).

Consequently, Sir Karl Popper advocated "falsificationism" instead. He conceded that evidence can never confirm a theory, but he proposed it can nevertheless falsify a theory. If scientists frame a theory, then test its empirical consequence in an experiment, and the experiment fails, he argued, then they are entitled to conclude the theory cannot be right. The logic of falsificationism is unquestionably valid. Most experimental scientists understand the perils of confirmationism—not often from reading philosophers but more often from the doggedly hard experience of doing science. Pressed further, many scientists will appeal to Popper's refrain that scientific theories, in contrast to other kinds of claims, can at least be falsified. So the falsificationist program believes it has salvaged a justifiable criterion of demarcation. Echoing Popper's argument, creationists take some aid and comfort from falsificationism; Darwinian evolution is "just a theory," as Reagan intoned, because it cannot be "proven" true,

Alas, it turns out that falsificationism fails as well because scientists can never be sure of the source of untoward experimental results. It might stem from experimental error or an auxiliary theory, rather than the theory being tested; all data, as Norwood Russell Hanson (1961) taught, are theory laden so that all experimental data embody a web of theoretical claims. There is, therefore, no proving or disproving of empirical theoretical claims in science since there is no theory-free evidence that can definitively confirm or disconfirm a proposed theory. Empiricism is dead, and attempts to revive it have failed. The nineteenth century may have deposed theology as the queen of the academy but the twentieth century decapitated empiricism as a philosophical bedrock for theoretical science.

The general failure to distinguish science from other claims to knowledge by means of logic and experimental evidence is called "underdetermination," a charismatically challenged word that names the most disconcerting limitative result in the history of academia. I tell my students that everything else I know pales by comparison and that the academy has only begun to digest this remarkable development.

At this point, many honors students are either unnerved, incredulous, roundly offended, or all three at the same time. As I remind them that I have served as the science division chair, I can sense some of them thinking, "with friends like you, science needs no enemies." But of all students, honors students ought not graduate with an oxymoronic, naïve faith in scientific method. Underdetermination is no justification for a self-refuting relativism: it does not entail the conclusion that science and Ouija boards are equally good routes to knowledge.

Instead, it affords an unparalleled opportunity in the honors classroom to address the larger question of how people justify their beliefs in general and how we identify which practices are most likely to lead to the most productive results. The authority of ancient texts and religious leaders has been under wide assault in the West for several centuries; most honors students appear in classes with this dramatic change well entrenched in their subconscious. Because science also stands in need of justification and has been challenged just as radically, the honors seminar door is opened to perhaps the first comprehensive discussion of the relation of belief to truth that such students have ever had.

Practice Makes Perfect

Rorty's pragmatist critique of American culture in general and science and religion in particular has played a significant role in the honors program's attempt to position science constructively in light of underdetermination. Rorty, it is true, can be read as denigrating science since he characterizes it as telling people "how things work" (2007, 98). And he contends that the idea that science can deliver reality as it is in itself is a forlorn, last-ditch effort to distill "redemptive truth" (2007, 95) from the manifold of chaotic appearance that people often mistake for reality. Provocatively, he argues that "the phrase 'Reality as it is in itself, apart from human needs and interests' is just another of the obsequious Names of God . . . the idea that physics brings humans closer to reality than morals is an updated version of the priests' claim to be in closer touch with God than the laity" (2007, 134).

With enemies like Rorty, science needs no friends. Rorty's contributions to positioning science wisely remind people that claims to truth are extraordinarily difficult to sustain philosophically and finally, in any case, unnecessary in science or any other human activity; people who claim to know the truth, he observes warily, are more likely to bully and kill each other. Instead, science deserves its place of distinction in the honors curriculum because it holds the greatest promise for the improvement of material circumstance, most notably health and the kind of leisure time that a free and civilized life presupposes. "Take care of freedom and truth will take care of itself" (Mendietta , 2006) is the pragmatist credo. Science's virtues in these terms are simply the best yet. Scientists no longer need the "science delivers truth" nostrum and should abandon it the way health practitioners abandoned ascribing diseases to demons.

In fact, I have found Rorty's positioning of science as a prerequisite to an egalitarian, maximally tolerant society to be a more compelling invitation to science than now indefensible claims to truth. "You mean we should study science because it holds out great promise for helping us create a more just society?" one student asked without raising a hand. "Indeed" was all I said in reply. Educators fail as honors instructors if they fail to make the connection between a just, maximally free society and a robust scientific community as a necessary condition for that society.

The chief glory of science and the principal motivation it should provide honors students for doing science, therefore, is that it enables cumulative improvement in humankind's material condition in a way that no other academic activity does as effectively. Creationism warrants little time in the science classroom not because it is demonstrably false or fails to be falsifiable—because no theory is either—and not because evolution has been proven true—since no empirical theory can be proven true—but because it has yielded no identifiable improvement in our material condition. When science convinces people "that there are no spooks" (Rorty, 2007, 100), it can pursue the business of improving the human condition without reference to transcendent causes. Scientific method is less a matter of logic interacting with evidence to generate truth than the collective, corrigible efforts to improve people's situation with the scientific constructs that are both intellectually compelling and productive. As a case in point, historians have often worried about the fact that Newtonian mechanics was so widely accepted as true when some now take it to be false since it incorrectly predicts, for example, electron behavior. A pragmatist view of science will point out that such worries stem from an unnecessary obsequy to a deified truth. Scientists pay more attention to base two than base three, not because it is truer but because it maps more productively onto electronic circuitry. Quantum mechanics may never be intelligible enough to label as "true," but given its great utility, this need not exercise scientists as it did Einstein. They need not stake the flag of science to the outsized claim that science provides a true or nearly true image of the world. They need not claim, as *Newsweek* reported, that scientists are in possession of proven theories. Such claims, I have attempted to argue, are beyond justification and needlessly erode the credibility of science at a time when science has never been more important to the future.

A number of years ago, a pre-med honors student came to my office after class, nearly in tears after a discussion of underdetermination, the limitative results conditioning the view of science, and the initially disconcerting conclusion that scientists can never justifiably claim that they have at last replaced appearance with reality. "Should I still be a doctor?" she asked wistfully. Worried that I had done more harm than good, I gently encouraged her dreams. She eventually became one of the honors program's best students and was admitted to a good medical school. Just last week I received a handwritten note from her. "I am in my third week of residency," she wrote, and she took self-effacing delight in emphasizing her medical "practice." She is at long last a physician; I suspect she will be a good one.

Questions for Discussion

1. Why does this paper argue that empirical theories in science cannot be proven true? What argument does the paper provide for concluding that "theories cannot be promoted to facts"?
2. Does the author, in your view, escape the charge that the paper finally—though perhaps unwittingly—espouses relativism, in this case the view that science is in no better position to guide our way in the world than superstition?
3. What is the difference between "confirmationism" and "falsificationism" and how, according to the paper, do the failures of both views of science entail underdetermination, which the author deems "the most disconcerting limitative result in the history of academia"?
4. Why does the writer believe that honors students, "of all students," ought to be conversant with the "limitative" results coming from philosophy of science and computational theory?
5. Why does the paper argue that honors students, who might otherwise not be interested in science, could be induced to take a renewed scientific interest, given the paper's claimed relationship between science and social justice?
6. What is the relationship between freedom and truth, according to the pragmatist "credo"? What are the implications for the kinds of discussions that should be sanctioned in honors classrooms? Are there any views or topics that should be ruled out of bounds, given this paper's claimed relation of freedom to truth?
7. Who would object more forcefully to the stance of this paper, a materialist evolutionist such as Jerry Coyne (2010), who has written that we know evolution by natural selection is true, or intelligent design advocate and biochemist Michael Behe (2008), who argues that some biological phenomena are so complex they require an intelligent designer? Explain your answer.

Recommended Reading

Fuller, Steve. *Kuhn vs. Popper: The Struggle for the Soul of Science.* New York: Columbia University Press. 2004.

Ward, Keith. *The Big Questions in Science and Religion.* West Conshoshocken: Templeton Press. 2008.

Suggestion for Honors Classroom Debate

Set up three teams for a spirited debate over the arguments in this paper: "Dawkins Darwinists" who maintain "science can deliver us truth and we now know Darwinian materialism is true"; "Behe Biologists," who argue that "people are smart enough to discover truth, including the truth that we need a Designer to make sense of all the phenomena we experience"; and "Pusillanimous Pragmatists," who contend that "truth as an idea has caused humanity more problems than it has solved and we should concentrate instead on what turns out to be productive."

Bibliography

"Are Today's Most Advanced Mathematical Proofs Impossible to Verify?" *Seed* Aug. 31, 2012. <http://www.seedmagazine.com/content/article/mathematical_uncertainty>. [article reissued]

"Beliefwatch Ivy League." *Newsweek* Jan. 22, 2007. <http://www.thedailybeast.com/newsweek/2010/02/10/harvard-s-crisis-of-faith.html>.

Behe, Michael. *The Edge of Evolution: The Search for the Limits of Darwinism.* New York: Free Press, 2008.

Berra, Tim M. *Evolution and the Myth of Creationism: A Basic Guide to the Facts in the Evolution Debate.* Stanford: Stanford University Press, 2008.

Chaitin, G. J. "Randomness in Arithmetic and the Decline and Fall of Reductionism in Pure Mathematics." *EATCS Bulletin* 50 (1993): 314–328. <http://arxiv.org/abs/chao-dyn/9304002>.

Coyne, Jerry. *Why Evolution Is True.* Oxford: Oxford University Press, 2010.

Franks, Curtis. *The Anatomy of Mathematical Knowledge: Hilbert's Program Revisited.* Cambridge: Cambridge University Press, 2010.

Hanson, Norwood Russell. *Patterns of Discovery: An Inquiry into the Conceptual Foundations of Science.* Cambridge: Cambridge University Press, 1961.

Kant, Immanuel. *Prolegomena to Any Future Metaphysics.* Toronto: University of Toronto Libraries, 2011.

Kosso, Peter. *Reading the Book of Nature.* Cambridge: Cambridge University, 1992.

Mendietta, Eduardo. *Take Care of Freedom and Truth Will Take Care of Itself: Interviews with Richard Rorty.* Stanford: Stanford University, 2006.

Popper, Karl. *The Logic of Scientific Discovery.* New York: Routledge, 2002.

Rorty, Richard."Pragmatist View of Contemporary Analytic Philosophy." In *The Pragmatic Turn in Philosophy: Contemporary Engagements Between Analytic and Continental Thought.* William Egginton and Mike Sandbothe, eds. New York: State University of New York, 2004. 131–144. <http://evans-experientialism.freewebspace.com/rorty04.htm>.

Rorty, Richard. *Philosophy as Cultural Politics: Philosophical Papers* Vol. 4. Cambridge: Cambridge University Press, 2007.

Wolfram, Stephen. *A New Kind of Science.* Champaign IL: Wolfram Media, 2002.

Chapter 19

CONFRONTING PSEUDOSCIENCE: AN HONORS COURSE IN CRITICAL THINKING

KEITH GARBUTT

Introduction

One of the challenges facing educators in mathematics and science is that students who are not in those disciplines are often phobic about the subject matter covered in these classes. In addition, even those students who are not put off by the material are unlikely to value classic chemistry, biology, or physics classes because they are rarely aimed at the needs of a non-science major. Even those classes that faculty design for non-majors are frequently little more than watered-down versions of the majors classes, which an examination of the textbooks aimed at such classes readily reveals.[1]

In thinking about classes that teach science to non-majors, scientists should ask themselves what type of information will be of most use to the students. Why do colleges require them to take science classes at all? The case has been well made that one of the most important parts of science education is giving students the habits of mind associated with the scientific process.[2] These include reasoning from evidence, applying logic, tolerating uncertainty, and understanding the concept of alternative hypotheses. Yet when faculty consider these particular outcomes, clearly they realize that they could use other material to give students the same habits of mind. The second reason to require non-science major students to take science courses is to protect them as consumers and citizens from the vast array of snake-oil merchants who are selling both commercial and political ideas and claiming that they are supported by science. A course that explicitly looks at spurious, fraudulent, and misleading science and that gives the students the intellectual tools to analyze and expose such flimflam can fulfill both criteria. Such a course can not only introduce students to the habits of mind associated with science but also to the content of science applied to daily circumstances. Hence, West Virginia University developed just such a course, Confronting Pseudoscience, for its honors students;

those students outside the sciences who wish to complete science distributions for their major but have no specific requirements for a particular discipline are the target audience.

Even though this course is for non-science majors, that it follows appropriate pedagogical techniques associated with science courses is important. The 2004 publication of the forum paper "Scientific Teaching" in *Science* lays out clearly the need for the teaching of science to be as rigorous as the way scientists approach their research.[3] "Scientific Teaching" strongly advocates the inclusion of active learning and appropriate assessment in science courses as one part of the structure necessary for this course.

Peterson and Jungck present an approach to science education known as the 3-P's.[4] This methodology breaks down the process of scientific investigation into three stages. The first is problem posing. Many good science curricula advocate inquiry-based learning, but they tend to present students with very specific, albeit open-ended questions to investigate. While this strategy is certainly a significant step forward from either simple lectures or cookbook laboratories, it perhaps misses one of the most important elements of the scientific endeavor. Peterson and Jungck point out that perhaps the single-most creative part of the scientific endeavor is the initial recognition of the problem that needs to be addressed. The second step of the 3-P's, problem solving, is examining the problem and finding a possible solution. This part of the process is one that many would, incorrectly, identify with doing science, that is the physical activity involved in an experiment, which is exemplified by the bubbling flasks of the mad scientist conjured by the media. The actual process, however, which is described here, is an intellectual process that in some cases may not actually involve a physical experiment. The final part is peer persuasion. One aim of the scientific enterprise is to produce a published paper. This peer-reviewed paper is the persuasion piece in which professional scientists communicate problems and their solution to the problems, or more usually their partial solution to the problem, to their peers for comment.

An important part of any class, assessment should actually measure the learning objectives of the course. All too often, even when courses are well designed and include active learning, assessments simply measure students' ability to memorize and regurgitate. A well-structured course should have both formative and summative assessment that clearly and unambiguously measures the learning objectives.[5]

General Overview

West Virginia University's course Confronting Pseudoscience essentially has three components that are necessarily intermixed throughout the course. The first component provides students with their tools. Through a mix of lectures, case studies, and active-learning exercises, all with associated formative assessments, students are introduced to the basic concepts of critical thinking, evidentiary reasoning, and judging authority. They are then shown how these skills can be brought together to investigate topics that claim to have a scientific basis. Students learn how to build web pages and how to prepare effective PowerPoint presentations that support oral presentations to hone their ability to persuade others. The second component of the course, which overlaps in time with the first, is when the students pose the problems they will try to solve. During this phase students identify topics, usually from the web, that are scientific or make claims that are backed by science and research. They work in groups and then as individuals, using the tools and skills previously acquired and the instructor as a resource and mentor, to investigate the claims. The final component of the course is the persuasion component: students build web pages that debunk pseudoscientific ideas, give presentations to their peers concerning these pseudoscientific concepts, and write a final paper. This final stage is also the summative assessment stage: the quality of the arguments in these papers and presentations allows the instructor to evaluate to what extent the students have mastered the tools of critical thinking.

Through this procedure students gain basic skills in critical thinking and reasoning and apply them to real problems, and while they address each of the problems, they find that they acquire basic science content. In order to evaluate claims, they must understand the underlying science and identify inappropriate applications.

Giving Students the Tools for Critical Thinking

As indicated above, the first part of this course is devoted to having students acquire the tools they need to analyze and assess the wide array of ideas and products that are supported by purported scientific evidence but which, in fact, are nothing more than pseudoscience. Initially the class looks at the difference between misconceptions and irrational thinking. As an example of common misconceptions, even amongst educated individuals, the students preview a modified version of the questions posed to Harvard University and MIT graduates in the

Minds of Our Own video.[6] Not surprisingly, many members of the class hold misconceptions about the workings of the natural world similar to those of the Harvard and MIT graduates. The class looks briefly at the source of these misconceptions and then moves to the topic of rational beliefs. Recent work in the cognitive sciences suggests that humans are evolutionarily predisposed to believing in irrational things.[7] The task becomes understanding the difference between rational and irrational beliefs. For example, after polling the class members on common phobias, such as the fear of spiders or flying, students investigate the actual risk associated with these activities. Statistics from the National Safety Council suggest that the probability of dying in a car accident is many thousands of times greater than the probability of dying in a plane crash, yet many people prefer to drive long distances rather than take a plane even when they are aware of these statistics.[8] This initial self-examination of the class and the assignment to read "Teaching Pigs to Sing" help students to understand why people may believe things that they perceive to be clearly ridiculous when they encounter misperceptions later in the semester.[9]

The next section of the course establishes the basic rules of critical thinking and evidential reasoning; this section is supported heavily by four papers: three papers from *Skeptical Inquirer* and a chapter from Carl Sagan's *The Demon-Haunted World: Science as a Candle in the Dark.*[10] After discussing the basic tenets of critical thinking and evidential reasoning, which include the ability to ask questions, the ability to define a problem, an understanding of the nature of assumptions, and the ability to tolerate temporary or provisional hypotheses, the class then explores different cases of pseudoscience that may violate one or more of the basic rules laid down in these papers.

Examples include the examination of ESP through the use of Zener cards, which were developed as a way of measuring purported extrasensory perception. It is not unusual, however, for the practitioners studying extrasensory perception to be willing to accept results which, when carefully analyzed, prove not to be statistically significant. The class undergoes three rounds of trials for ESP using Zener cards. Students then tabulate the results of the class. For at least one member of the class to have an outlying score that is relatively high is not unusual. The class then reviews the distribution of scores based on chance to determine whether this outlier can be attributed to ESP or whether assuming that it is nothing more than one lucky event appears more reasonable.

Five classes have carried out this activity. On one occasion a student scored exceptionally high marks, in fact significantly beyond what one would expect from chance. Of course, this result caused some consternation within the class. After talking about it for some time, the class eventually decided to test the individual again to determine if that person really did have ESP. If an unknown scientific principle was at work, the results would be repeatable. Near the end of the first round of the second series of tests, the individual was still achieving exceptionally high scores. At this point I realized that this individual was sitting in a position in the classroom where it might be possible to see the reflection of the Zener Cards in my spectacles. I removed my spectacles and proceeded with the trial. The individual's score dropped to below average at the end of the trial. In trying to explain the results, most students remained mystified; some wonder if some trick had been played. At that point, the individual confessed to reading the cards from my spectacles. This revelation provided an exceptionally good lesson for the class because it significantly increased the tendency of the class to look for mundane reasons for apparently startling results.

Another element of the course is looking at a series of case studies. Students review the information behind a pseudoscientific topic such as creationism. They analyze the underlying fallacies and *non sequiturs* within the pseudoscience, investigating the contradictions and deliberate misquotations that bolster the claims of creationism. This topic provides an excellent opportunity to discuss how to assess the level of authority that can be assigned to different sources and also the concept that facts always trump authority.[11] The group also looks at the controversies within the different branches of creationism and the arguments concerning intelligent design. (See Table 1 for readings.)

The class also views video clips of other practitioners of the art of debunking, such as Penn and Teller's *Bullshit*.[12] One particularly useful segment from their show is a piece on Feng Shui. Feng Shui purports to be the scientific method of manipulating energy, called "qi," to increase the prosperity of the individuals in the household. Penn and Teller arrange what is essentially a scientific test of Feng Shui. They hypothesize that if Feng Shui is a science, the outcome of an analysis of a house should be the same irrespective of the practitioner. They ask three Feng Shui specialists to analyze the same house. Perhaps not unexpectedly, the result is that all three specialists provide completely different solutions, thus causing Penn and Teller to reject the hypothesis. This example is particularly useful because Penn and Teller are actually applying the principles of scientific reasoning to a pseudoscience.

Posing the Problem

At this point the students begin to think about the issues that they might be interested in assessing. They are required to look at three different topics. For two of these topics, they work as part of a group and for the third they work as individuals. They are provided with a wide range of resources to help them understand the different aspects of pseudoscientific claims and to help them understand how pseudoscience can be presented to the public to make it appear scientific and reasonable. (See Table 1 for a reading list about pseudoscience.) The first of these pseudoscientific topics is always based on a large, overarching concept, which is chosen by the class. Starting this way promotes significant interactions among the individuals and their groups. Students learn from one another as they move through the process of analyzing their own particular section of the larger topic, and they build the necessary skills to work on the next project as a group and then on their final project as individuals.

Some topics have been investigated previously by classes; others may be new. The basic guidelines are that the topic must be broad enough for there to be subtopics for each of the groups and that the practitioners of the topic must claim that what they are doing has a scientific basis. Some of the most successful of these topics have involved cryptobiology, where students investigate the evidence for the existence of exotic organisms like Big Foot or the Loch Ness monster. UFOs also offer an almost unlimited array of subtopics, including one wonderful local example in the Flatwoods monster, the local legend of a supposed UFO and extraterrestrial encounter at Flatwoods, West Virginia, in 1952.[13] As with UFO's, alternative medicines, particularly applied to the treatment of AIDS, offer a remarkably wide array of subtopics, which typically pose an intellectual as well as an emotional challenge to the students. For example, the students became quite angry when they realized how practitioners of various alternative therapies were cynically exploiting the very real fears of people with AIDS to make large amounts of money from worthless treatments.

Problem Solving and Persuasion

As the semester proceeds, the class metamorphoses from a lecture experience to a laboratory experience. The students begin by working in groups on the overall class project and then work on individual group projects and individual projects. The role of the instructor migrates to that of a mentor and resource who moves from group to group or individual to individual, helping them to become independent researchers.

Intermingled with these activities is a practical part of the course: students learn how to build web pages. With the advent of modern tools for visual web-page construction, students need not learn to code in HTML. Simple and effective web pages can be made quite easily even by the most technophobic student. One of the most important parts of this learning experience is using the web as an effective communicating tool. Initially students are inclined to make garish and active web pages; however, after they review web pages that they personally use and feel are effective, they recognize that effective ones share certain traits. They tend to be relatively plain and have significant content that is thoughtfully distributed between graphics and carefully controlled text. The students also notice that using hyperlinks adds depth to these pages. On the basis of these analyses, the students will typically redesign their own pages to make them more appealing and to ensure that they contain significant content.

Students also make oral presentations on their topics. Since they are accustomed to seeing PowerPoint presentations, they usually choose this format. On occasion, students have effectively deconstructed products or advertisements by using the Socratic Method with the class; in effect, they are exploring some of the pedagogical models presented earlier in the course. Class time is spent looking at effective uses of PowerPoint since so many groups use PowerPoint. Once again students use their own experience to create lists of the good and bad presentations they have seen to analyze what they find appealing in a good PowerPoint presentation. In class students quickly realize that different people are responding to different aspects within a PowerPoint presentation and that a PowerPoint presentation should offer at least a 50/50 mix of graphics and text and use sound or video. During the final weeks of the class, the students make their presentations to the class on the topics they have been researching and post their web pages to the Internet.

Outcomes

In general, the research assignments for this course are excellent, as one might expect from honors students. Students with little or no background in science are motivated to learn significant amounts of chemistry, biology, and physics in order to understand the background needed to analyze their topics. Some of the most successful projects have included a group project on anti-aging creams and a study of magnetic therapy. None of the students who conducted the anti-aging cream study were science majors, yet they presented an outstanding discussion of these cosmetic products and their claims, and they bolstered their critique of the products, the vast majority of which have no effect upon the wrinkles, with information from chemistry and physiology. Similarly, another group working on magnetic therapy mastered concepts in physics and biology to debunk the claims of the manufacturers.

One of the most interesting outcomes of this course is the appreciation that the students develop for the processes of science. The final papers produced by the students provide a substantive assessment of the students' understanding of the scientific method, critical thinking, evidential reasoning, and their application to real-world problems. In these papers students demonstrate that they understand the basic principles of the scientific method and how these principles can be applied to a range of ideas. They show creativity and remarkably sophisticated analysis in their treatment of their chosen pseudoscience. Students are applying complex scientific principles to the assessment of the claims of their particular topic. In the final analysis, students who take this course leave it with a set of tools that will allow them to approach the claims of others logically and critically.

Table 1

Reading List for Confronting Pseudoscience (Spring 2007)

Required Texts

Ben-Ari, Moti. *Just a Theory: Exploring the Nature of Science.* Amherst, NY: Prometheus Books, 2005.

Park, Robert L. *Voodoo Science: The Road from Foolishness to Fraud.* Oxford: Oxford University Press, 2000.

Sagan, Carl. *The Demon-Haunted World: Science as a Candle in the Dark.* NY: Random House, 1996.

Shermer, Michael. *Science Friction: Where the Known Meets the Unknown.* NY: Times Books, 2005.

Set Readings (Articles are posted or linked from on a secure e-learning website as appropriate.)

Ben-Ari, Moti. "Just a Theory: What Scientists Do." In *Just a Theory: Exploring the Nature of Science,* by Moti Ben-Ari, 23–41. Amherst, NY: Prometheus Books, 2005.

Ben-Ari, Moti. "Science and Religion: Scientists Just Do Science." In *Just a Theory: Exploring the Nature of Science,* by Moti Ben-Ari, 131–138. Amherst, NY: Prometheus Books, 2005.

Gabennesch, Howard. "Critical Thinking: What is it good for? (In fact, what is it?)." *Skeptical Inquirer* 30, no. 2 (March/April 2006): 36–41.

Hall, Harriet. "Teaching Pigs to Sing: An Experiment in Bringing Critical Thinking to the Masses." *Skeptical Inquirer* 30, no. 3 (May/June 2006): 36–39.

Krieg, Eric. "Examining the Amazing Free-Energy Claims of Dennis Lee." *Skeptical Inquirer* 21, no. 4 (July/August 1997): 34–36.

Lett, James. "A field guide to critical thinking." *Skeptical Inquirer* 14, no. 2 (Winter 1990): 153–160.

Lipps, Jere H. "Judging Authority." *Skeptical Inquirer* 28, no. 1 (January/February 2004): 35–37.

Loftus, Elizabeth F., and Melvin J. Guyer. "Who Abused Jane Doe? The hazards of the single case history. Part 1." *Skeptical Inquirer* 26, no. 3 (May/June 2002): 24–32.

Loftus, Elizabeth F., and Melvin J. Guyer. "Who Abused Jane Doe? The hazards of the single case history. Part 2." *Skeptical Inquirer* 26, no. 4 (July/August 2002): 37–44.

Park, Robert L. "It's Not News It's Entertainment: In which the Media Covers Voodoo Science." In *Voodoo Science: The Road from Foolishness to Fraud,* by Robert L. Park. Oxford: Oxford University Press, 2000: 3–27.

Park, Robert L. "There Ought to be a Law: In which Congress seeks to repeal the Laws of Thermodynamics." In *Voodoo Science: The Road from Foolishness to Fraud,* by Robert L. Park. Oxford: Oxford University Press, 2000: 92–110.

Pigliucci, Massimo. "Design Yes, Intelligent No: A Critique of Intelligent Design Theory and Neocreationism." *Skeptical Inquirer* 25, no. 5 (September/October 2001): 34–39.

Radford, Benjamin. "Bigfoot at 50: Evaluating a Half-Century of Bigfoot Evidence." *Skeptical Inquirer* 26, no. 2 (March/April 2002): 29–34.

Rosa, Linda, Emily Rosa, Larry Sarner, and Stephen Barrett. "A Closer Look at Theraputic Touch." *Journal of the American Medical Association* 279, no. 13 (1998): 1005–1010.

Sagan, Carl. "The Fine Art of Baloney Detection." In *The Demon-Haunted World: Science as a Candle in the Dark.* New York, NY: Random House, 1996: 201–218.

Shermer, Michael. "The New New Creationism: Intelligent Design Theory and its Discontents." In *Science Friction: Where the Known Meets*

the Unknown, by Michael Shermer. New York, NY: Times Books, 2005: 173–199.

Wade, Carole, and Carol Tavris. "Thinking Critically and Creatively." *Skeptical Inquirer* 14, no. 4 (Summer 1990): 372–377.

Biblioigraphy

Atran, Scott. *In Gods We Trust:The Evolutionary Landscape of Religion.* New York: Oxford University Press, 2002.

Campbell, Neil A., Jane B. Reese, Martha R. Taylor, and Eric J. Simon. *Biology: Concepts & Connections.* San Francisco: Pearson/Benjamin Cummings, 2006.

Hall, Harriet. "Teaching Pigs to Sing. An Experiment in Bringing Critical Thinking to the Masses." *Skeptical Inquirer* 30, no. 3 (May/June 2006): 36–39.

Handelsman, Jo, Diane Ebert-May, Robert Beichner, Peter Bruns, Amy Chang, Robert DeHaan, Jim Gentile, Sarah Lauffer, James Stewart, Shirley M. Tilghman, and William B. Wood. "Scientific Teaching." *Science* 304, no. 5670 (April 2004): 521–522.

Jillett, Penn, and Teller. "Feng Shui/Bottled Water." Episode 7, *Bullshit.* Showtime Networks, Inc., 2003.

Lipps, Jere H. "Judging Authority." *Skeptical Inquirer* 28, no. 1 (January/February 2004): 35–37.

Moore, John A. *Science as a Way of Knowing: The Foundations of Modern Biology.* Cambridge: Harvard University Press, 1993.

National Safety Council. *Injury and Death Statistics* (National Safety Council, 2012).

Nickell, Joe. "The Flatwoods UFO Monster." *Skeptical Inquirer* 24, no. 6 (November/December 2000): 15–19.

Peterson, Nils S., and John J. Jungck. "Problem-Posing, Problem-Solving, and Persuasion in Biology Education." *Academic Computing* 2, no. 6 (March-April 1988): 14–18, 48–50.

Sagan, Carl. "The Fine Art of Baloney Detection," In *The Demon-Haunted World: Science as a Candle in the Dark.* New York: Random House, 1996.

Science Media Group. Harvard-Smithsonian Center for Astrophysics. *Minds of Our Own.* South Burlington, VT: Annenberg/CPB Math and Science Collection, 1997.

Notes

[1]Neil A. Campbell, Jane B. Reese, Martha R. Taylor, and Eric J. Simon, *Biology: Concepts & Connections.* 5th ed. San Francisco: Pearson/ Benjamin Cummings, 2006.

[2]John A. Moore, *Science as a Way of Knowing: The Foundations of Modern Biology* (Cambridge, MA: Harvard University Press, 1993).

[3]Jo Handelsman, Diane Ebert-May, Robert Beichner, Peter Bruns, Amy Chang, Robert DeHaan, Jim Gentile, Sarah Lauffer, James Stewart, Shirley M. Tilghman, and William B. Wood, "Scientific Teaching," *Science* 304, no. 5670 (April 23, 2004): 521–522.

[4]Nils S. Peterson and John J. Jungck. "Problem-Posing, Problem-Solving, and Persuasion in Biology Education," *Academic Computing* 2, no. 6 (March–April 1988): 14–18, 48–50.

[5]Jo Handelsman et al., "Scientific Teaching."

[6]Science Media Group, Harvard-Smithsonian Center for Astrophysics, *Minds of Our Own* (South Burlington, VT: Annenberg/ CPB Math and Science Collection, 1997).

[7]Scott Atran, *In Gods We Trust: The Evolutionary Landscape of Religion* (New York: Oxford University Press, 2002).

[8]Data for risk associated with a wide range of activities can be found at the National Safety Council, *Injury and Death Statistics Web site:* <http://www.nsc.org/news_resources/injury_and_death_statistics/Pages/InjuryDeathStatistics.aspx>. 2012.

[9]Hall, Harriet. "Teaching Pigs to Sing: An Experiment in Bringing Critical Thinking to the Masses," *Skeptical Inquirer* 30, no. 3 (May/June 2006): 36–39.

[10]Sagan, Carl, "The Fine Art of Baloney Detection," in *The Demon-Haunted World as a Candle in the Dark* (New York: Random House, 1996).

[11]Lipps, Jere H. "Judging Authority." *Skeptical Inquirer* 28, no. 1 (January/February 2004): 35–37.

[12]Penn Jillett and Teller. "Feng Sui/Bottled Water," Episode 7, *Bullshit.* Showtime Networks, Inc., 2003.

[13]Joe Nickell, "The Flatwoods UFO Monster," *Skeptical Inquirer* 24, no. 6 (November/December 2000): 15–19. The Flatwoods monster was nicely debunked in this article.

Chapter 20

SCIENCE EDUCATION: THE PERILS OF SCIENCE ILLITERACY, THE PROMISE OF SCIENCE EDUCATION

GLENN M. SANFORD

The media in America often report on the state of public schools and the quality of the educational system in general. Coupled with a resurgence of evangelical Christianity, this attention has vaulted the politics of public school science curricula debates to the front pages. Although intelligent design and other "alternative approaches" have failed to gain ground within the mainstream scientific community, they have captured the popular imagination and garnered political support in a variety of areas. Questions of demarcation arise in a number of areas when one considers the hearings held by the Kansas Board of Education,[1] the federal court decision in *Kitzmiller v. Dover Area School District*,[2] global warming,[3] or disclaimers in biology textbooks.[4] Although people discuss these debates under the guise of science vs. religion, local vs. national control of education, real science vs. junk science, and open vs. closed mindedness, at their heart, these debates represent attempts to apply the philosophy of science to the practical issue of establishing the appropriate presentation of science in educational settings. [5]

These debates notwithstanding, teachers bemoan teaching to the test, and students complain about boring science courses. These factors should lead scientists to ask how the conception of science affects not only the decisions about what to teach but also how to teach science. The response to these issues will affect students' perspectives on science. The question about what should be included within the scientific rubric has taken center stage in these debates. Two prominent features of these debates have been practicing scientists expressing frustration at their opponents' misrepresentation of science and scientific practices and opponents of evolution and global warming stressing critical thinking, critical inquiry, and academic freedom.[6] A third and more troubling feature is the public attitudes concerning these debates: "I don't see what all this fuss is about." "Just teach the alternatives and let students make up their own minds." "I don't see why I need to take science classes; it's not like I will ever use it."[7] Such comments reveal an insidious problem. Education has failed to connect science practice and science education. If this failure is present in honors science courses, the situation is even more tragic and disheartening.

An essential feature of science is the revision of its theories in the face of new evidence. That scientists have dismissed as wrongheaded theories previously accepted as scientific is well established. For example, the theory that stress caused the majority of peptic ulcers has been replaced by the theory that they are caused by the bacterium *Heliobacter pylori.* If the goal is to provide a science curriculum that will be useful throughout students' lives, the education must transcend teaching currently accepted theories and lists of facts. Students must understand the methods and practices of science in a manner that allows them to comprehend that theories will change and to apply the principles of science to decision making in their own lives. The key, then, is not defining science or establishing specific criteria for determining whether or not a particular theory is scientific. What is critical is that students comprehend the nature of scientific literacy and recognize the advantages of developing their literacy to merely accumulating more theories and facts.

One easy way to define scientific literacy is by referring to the characteristics of a scientifically literate person; they include 1) a broad acquaintance with current theories, including knowledge of how these can be applied; 2) an understanding of how science proceeds, especially its methods, practices, and evidence evaluation; and 3) the ability to apply #1 and #2 to solving individual and social problems. This list is not exhaustive; however, the three components provide the central core of the concept. The broad acquaintance with current theories provides fodder for discussion of scientific practices and a starting point for discussions of how scientific principles can be used in problem solving. In regard to lifelong learning, the second component is the most important. It provides the tools for evaluating evidence and addressing future changes in theory. Finally, the third component stresses the need to ensure the relevance of science education within society. A scientifically literate person need not know any particular theory and may, in fact, be ignorant with respect to many areas of science; however, those people who meet the above requirements should be in a position to evaluate the relative merits of theories and predictions in areas beyond their specific knowledge.

The essential feature of literacy is people's ability to use current knowledge of science to investigate new areas as the need arises. For example, a scientifically literate individual may be ignorant of human metabolism; however, when diagnosed with a metabolic disorder, this individual would possess the skills to research the condition and ask questions of medical providers. Thus, the focus is shifting from presenting specific theories and facts to establishing a basis for ongoing learning. Student apathy and complaints about general education requirements are nothing new; however, within current science education, the students may have a point. In defense of the countless students who have complained about being forced to take general education science courses, their questioning the value of studying the anatomy of an earth worm or even a human, the atomic weight of elements, or a laundry list of physical laws is fair. When students face a Scantron-graded course that stresses memorization, the foregoing examples are of little or no practical value, and student frustration is warranted. Such courses and tests do little to promote scientific literacy; however, they do shape students' attitudes toward science. Because the focus is on memorizing facts, students rarely encounter opportunities to appreciate the methods of science or evaluate evidence to improve their own decision-making skills.

My high school earth science teacher taught global cooling, plate tectonics, the hydrological cycle, and a range of other topics by presenting a list of equations or facts to memorize. This pedagogical approach continued in college; as a freshman chemistry major, I was told by my professor: "Don't ask questions like that, just learn the material." Looking back on these experiences, I recall how at odds those classes were with my experience in a high school anatomy and physiology class where the instructors encouraged students to ask questions about the interrelationships among chemistry, biology, and physics in the context of overall bodily organization and function. This sense of science as an enterprise centered on questions and data as opposed to facts only returned when I began taking graduate biology classes while pursuing my PhD in the philosophy of biology. I stopped taking science classes after my freshman year to double major in math and philosophy because both areas offered more opportunity for asking questions than the science education I had been exposed to in my freshman year. I relate my experience here because it parallels what I have heard from countless students during advising sessions in which talented and curious students seek an escape from science classes that promise to bore them into submission.

As an example, during the past fifty years of climate science since J. Murray Mitchell's publication of "On the World-wide Pattern of Secular

Temperature Change," which reported a global cooling trend that had begun in the 1940's, scientists widely accepted and taught global cooling to many students in the 1970s.[8] Yet, in a single generation, scientific consensus has shifted; scientists now believe that global temperature is trending in the opposite direction.[9] For those whose science education focused on facts and theories, this inconsistency points toward junk science or worse, a hoax by powerful political interests. Many people take this change in emphasis and shifting nature of the so-called facts as clear evidence that this research is not real science. Unfortunately this analysis, although simple and direct, fails to account for the tentativeness of scientific findings and the role of new data in producing theory change. For those whose science education solely consisted of learning the facts and theories, however, this analysis is the only type available.

A similar situation exists with respect to evolutionary biology. Despite the federal courts having decided that biblical creation, creation science, and intelligent design are not sufficiently scientific for inclusion in public school classrooms,[10] Michael Berkman, Julianna Pacheco, and Eric Plutzer found that, as of the 2006–2007 school year, 25% of high school biology teachers still included creationism or intelligent design in their classes.[11] A constant refrain from opponents of teaching evolutionary theory is that educators should teach the controversy.[12] After all, opponents of teaching evolution claim that numerous biological phenomena cannot be explained by evolutionary theory; thus students should be presented alternative explanations and allowed to make up their own minds. This approach can work, but only if students are given the tools to judge scientific theories according to the standards of science.

Without doubt, evolutionary biologists cannot fully explain numerous biological phenomena; moreover, innumerable controversies exist within evolutionary biology. This situation is the case for all sciences. Physics, chemistry, geology, and every other science face phenomena that cannot be explained at present and may never be explained. Scientifically literate people expect and accept that this characteristic is a fundamental aspect of science; they realize science has only partial (or even no) explanations for certain phenomena. Additionally, within the understanding of how science proceeds, students would be expected to appreciate the principle of parsimony—scientists should prefer simpler explanations. Occam's razor, the principle that one should not postulate physical or metaphysical entities beyond necessity, stresses the need to promote simple and direct explanations over those that involve the insertion of supernatural powers or actors. With an understanding of the workings of science, students can easily address the creation/evolution debate within science.

In this context, people must consider the merits of the mainstream biological community stating that scientists do not know how the first cells were organized, but they have some hypotheses relative to the claims of intelligent design proponents who contend that these cells were organized by an intelligent designer. The scientific answer is obviously less complex. The intelligent design proponents fail to acknowledge that science need not have an explanation for everything. Additionally, their proposal violates the principle of parsimony with no concomitant explanatory return. The admission that scientists do not know everything does not satisfy the desire to find an explanation. When intelligent design proponents assert that they can better explain many of the intricacies of life, they offer little more than window dressing on the fact that much is unknown. Claiming that the cells were organized by an intelligence that cannot be described and via a process or processes that they know nothing about while offering no account of how they would learn about the processes or mechanisms is not an explanation of the intricacies of life. In essence, the insight that intelligent design offers is that phenomena exist that mainstream biologists have yet to explain, and this revelation does nothing to advance understanding. Inserting an additional physical or metaphysical entity as a placeholder for what mainstream biology has not yet explained is insufficient to establish the scientific *bona fides* of intelligent design's purported explanation.[13]

At this point, noting once again that scientifically literate people will also recognize the limits of science is important. Science by its nature is limited to the study of natural phenomena. When I consider my father's death, I know that he died of heart failure caused by the extra load created as his lungs failed because of interstitial pneumonitis, a degenerative lung condition marked by scarring the lining of the lungs. I also know that my stepfather died of cancer most directly attributable to forty years of heavy smoking and an employment history that included industrial solvents and paints. Nonetheless, I have spent countless hours wondering why they contracted those diseases and why I did not have the chance to share countless experiences as I completed my education, achieved goals, got married, suffered setbacks, and traveled. Science cannot provide answers to the latter questions at the level that I, and many others in similar situations, have sought. The questions I lose sleep over are not the type that science is designed to answer. Conversely, in 1837, William Buckland, an avid defender of the idea that science and revelation elucidate each other, provided an eloquent statement of the need for science within a religious worldview: "The disappointment of those who look for a detailed account of geological phenomena in the Bible, rests on a gratuitous expectation of finding therein historical information, respecting all the operations of the Creator in times and places with which the human race has no concern . . . the details of which may be a fit matter for an encyclopedia of science, but are foreign to the objects of a volume intended only to be a guide of religious belief and moral conduct" [sic].[14] It is essential that honors programs educate students concerning the ways in which science and religion can inform our decision making. Neither offers a one-size-fits-all solution to the problems people will face throughout their lives.

Upon hearing the story of a man who allowed his wife to die rather than permit a transfusion, many students express dismay and anger. Casting this scenario as an instance in which science and religion come into conflict is easy; however, to do so oversimplifies the issue and actually introduces a conflict where none exists. The conflict is not about the facts of the case: it is about the appropriate way to value process and outcomes. The husband understands that a blood transfusion would have saved his wife. He does not dispute that fact. He has expressed nearly continuous remorse concerning her passing. Yet, he stands by his decision as the only choice he had that would respect his wife's beliefs and protect her soul and spiritual wellbeing. He and his wife did not have beliefs that conflicted with science. Science provided the techniques for saving her life. Her husband, acting in accord with her religious beliefs, acknowledges the techniques but chose not to use them. Thus, this case involves the relative value of outcomes rather than a conflict between science and religion. Science can explain that mixing ammonia and bleach is a simple and effective way to produce chlorine gas, but understanding this process does not imply that people should be making chlorine gas.

Many people can respect the decision of an adult to forego a potentially life-saving treatment for personal reasons. When they read about children who died from untreated diabetes because their parents chose to rely upon prayer rather than seek medical care for them, many people are troubled and cannot understand how parents could allow their child to die in this fashion.[15] This situation presents a much more difficult scenario. In the former case, all parties involved acknowledge that all the evidence points to a blood transfusion as the most effective treatment for a patient who is bleeding out. Additionally, the choice to forego the transfusion was made respecting the well-established wishes of a competent adult. The case for children is different. If parents choose not to use insulin because such a choice violates a religious tenet, the case is not about the conflict between science and religion but rather between value systems. If parents claim that prayer healing is more effective than an insulin regime for a diabetic, the conflict would be between science and religion because such claims can be tested and decided based upon evidence from observed outcomes. Given the wealth of controlled studies supporting insulin therapy and the lack of such studies supporting prayer, the only scientific conclusion available is that insulin would have been an effective treatment. In a recent court case that follows this paradigm, the mother of a deceased girl testified in court that she believed in the power of prayer and that she felt seeking help from medical doctors would have represented "disobedience by demonstrating a lack of trust in God."[16] Discussing felony homicide charges against the parents, District Attorney Jill Falstad stated, "The failure to seek medical intervention created an unreasonable and substantial risk of death or great bodily harm."[17] The criminal charges in this case represent a clear position by the State that parents may not simply choose to follow their belief when clear evidence exists, pointing to an alternative course of treatment that would have saved a child's life.

Recognition of the strengths and limitations of science is essential for a quality education in science. Helping students achieve scientific literacy provides them with the basis for lifelong learning and continued growth within an increasingly technological society. Additionally, as issues such as global warming, cloning, and stem cell research continue to develop, producing citizens who can apply what they have learned to competently evaluate the promise and perils of these issues, opportunities, and crises is important. Budgetary pressures, fear of controversy, and calls for accountability, however, have promoted the development of bland introductory science courses, particularly for non-majors, that focus on having students memorize the facts. Unfortunately, such courses become boring and pedagogically unsound history of science courses. If the goal of science courses is to teach students about science, then the content must go well beyond memorizing facts to include aspects of scientific reasoning, scientific methodologies, and the application of this work to the problems facing students and the world they inhabit. Rather than teaching students to dread or mistrust science, science classes should emphasize scientific literacy.

Bibliography

Alters, Brian J., and Craig E. Nelson. "Teaching Evolution in Higher Education." *Evolution* 56, no. 10 (2001): 1891–1901.

Associated Press. "Homicide Charges for Parents Who Prayed as Daughter Died." *ABC News.* April 28, 2008. <http://abcnews.go.com/Health/Story?id=4741392&page=1> (accessed June 10, 2012).

Berkman, Michael B., Julianna S. Pacheco, and Eric Plutzer. "Evolution and Creationism in America's Classrooms: A National Portrait." *PLos Biology* 6, no. 5 (2008): 920–924.

Bleckman, Charles A. "Evolution and Creationism in Science: 1880–2000." *BioScience* 56, no. 2 (2006): 151–158.

Buckland, William. *Geology and Mineralogy with Considered Reference to Natural Theology.* Vol. 1. 2 vols. London: William Pickering, 1837.

Carpenter, Siri. "Kansas Cuts Evolution from the Curriculum." *Science* 156, no. 8 (1999): 117.

Cray, Dan. "God vs. Science." *Time Magazine.* November 5, 2006. <http://www.time.com/time/magazine/article/0,9171,1555132,00.html> (accessed June 10, 2010).

Davis, Derek H. "Kansas Schools Challenge Darwinism: The History and Future of the Creationism-Evolution Controversy in American Public Education." *Journal of Church & State* 41, no. 4 (September 1999): 661–676.

Discover Institute. *Articles Advocating Teaching the Controversy.* July 3, 2005. <http://www.discovery.org/a/2633> (accessed May 17, 2010).

Edwards v. Arkansas. 482 U.S. 578 (U.S. Supreme Court, June 19, 1987).

Epperson v. Arkansas. 482 U.S. 578 (U.S. Supreme Court, June 19, 1987).

Expelled: No Intelligence Allowed. Directed by Nathan Frankowski. Produced by Rampart Films. Performed by Ben Stein. 2006.

Forest, Barbara. "Understanding the Intelligent Design Creationism Movement: Its True Nature and Goals." *The Center for Inquiry Office of Public Policy.* July 2007. <http://www.centerforinquiry.net/uploads/attachments/intelligent-design.pdf> (accessed May 18, 2010).

Freiler v. Tangipipahoa Parish Board of Education. 201 F.3d 602 (5th Circuit, January 24, 2000).

Glauber, Bill. "Parents Prayed with Ministry Founder." *Journal Sentinel.* March 28, 2008. <http://www.jsonline.com/news/wisconsin/29556439.html> (accessed May 10, 2010).

IPCC. *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II, and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Intergovernmental Panel on Climate Change, Geneva, Switzerland: IPCC, 2007.

Kitzmiller v. Dover Area School District. 400 F. Supp. 2d 707 (M.D. Pennsylvania, December 20, 2005).

Math Drudge. *Creationism, Global Warming Denial, and Scientific Integrity.* March 2010. <http://experimentalmath.info/blog/2010/03/creationismglobal-warming-denial-and-scientific-integrity/> (accessed May 17, 2011).

McLean v. Arkansas Board of Education. 529 F. Supp. 1255 (E.D. Arkansas, January 5, 1982).

Meyer, Stephen C. "Teach the Controversy." *Center for Science and Culure.* March 30, 2002. <http://www.discovery.org/a/1134> (accessed May 18, 2010).

Miller, Kenneth. *Finding Darwin's God: A Scientist's Search for Common Ground Between God and Evolution.* New York: Harper Collins, 2000.

Mitchell, J. Murray. "On the World-wide Pattern of Secular Temperature Change." *Changes of Climate: Proceedings of the Rome Symposium Organized by UNESCO and the World Meteorological Organization, 1961.* Paris: UNESCO, 1963. 161–181.

Robertson, Colby. "Leilani Neuman Takes Stand is [sic] Husband's Trial." *WFXS Fox 55.* October 8, 2009. <http://www.myfoxwausau.com/dpp/news/wausau/Leilani_Testifies1008> (accessed May 10, 2010).

Sataline, Suzanne. "A Child's Death and a Crisis of Faith." *Wall Street Journal.* June 12, 2008. <http://online.wsj.com/article/SB121322824482066211.html> (accessed June 10, 2012).

Selman v. Cobb County School District. 390 F. Supp. 2d 1286 (N.D. Georgia, January 13, 2005).

Selman v. Cobb County School District. 449 F. 3d 1320 (11th Circuit, May 25, 2006).

Signham, Mano. "The New War Between Science and Religion." *The Chronicle of Higher Education.* May 9, 2010. <http://chronicle.com/article/The-New-War-Between-Science/65400> (accessed June 10, 2010).

State ex rel. Cornellier v. Black. 144 Wis. 2d 745, 425 N.W. 2d 21 (Court of Appeals of Wisconsin, April 21, 1988).

Talk.Origins. *Index to Creationist Claims.* Edited by Mark Isaak. 2006. <http://www.talkorigins.org/indexcc/> (accessed August 31, 2012).

Wilkins, John S., and Wesley R. Elsberry. "The Advantages of Theft Over Toil: The Design Inference and Arguing from Ignorance." *Biology and Philosophy* 16 (2001): 711–724.

Notes

[1]Charles A. Bleckman, "Evolution and Creationism in Science: 1880–2000," *BioScience* 56, no. 2 (2006): 151–158; Siri Carpenter, "Kansas Cuts Evolution from the Curriculum," *Science News* 156, no. 8 (1999): 117.

[2]*Kitzmiller v. Dover Area School District,* 400 F. Supp. 2d 707 (2005).

[3]IPCC, 2007: *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R. K. Pachauri and A. Reisinger, eds.]. IPCC, Geneva, Switzerland, 104 pp.; "Creationism, Global Warming Denial, and Scientific Integrity," *Math Drudge* website last accessed May 17, 2010, full URL: <http://experimentalmath.info/blog/2010/03/creationism-global-warming-denial-and-scientific-integrity/>.

[4]*Selman v. Cobb County School District,* 390 F. Supp. 2d 1286 (Northern District of Georgia 2005); *Selman v. Cobb County School District,* 449 F.3d 1320 (11th Circuit 2006) (vacating 2005 decision and remanding for further fact finding); *Freiler v. Tangipahoa Parish Board of Education,* 201 F.3d 602 (5th Cir. 2000).

[5]Mano Singham, "The New War Between Science and Religion," *The Chronicle of Higher Education* (2010) website last accessed June 10, 2012, full URL: <http://chronicle.com/article/The-New-War-Between-Science/65400>; Frankowski, Nathan (2008) *Expelled: No Intelligence Allowed,* Rampart Films; Cray, Dan (2006) "God vs. Science," *Time Magazine,* website last accessed June 10, 2012, full URL: <http://www.time.com/time/magazine/article/0,9171,1555132,00.html>; Derek H. Davis, "Kansas Schools Challenge Darwinism: The History and Future of the Creationism-Evolution Controversy in American Public Education," *The Journal of Church & State* 41, no. 4 (1999): 661–676.

[6]Compare *The TalkOrigins Archive: Index to Creationist Claims* website last accessed May 17, 2010, full URL: <http://www.talkorigins.org/indexcc/> with *Discover Institute: Articles Advocating Teaching the Controversy,* website last accessed May 17, 2010, full URL: <http://www.discovery.org/a/2633>.

[7]These comments represent a sample of the remarks that I have heard while doing presentations on the history of the legal debates concerning evolution and religion at conferences and public presentations.

[8]J. Murray Mitchell, (1963) "On the World-wide Pattern of Secular Temperature Change," *Changes of Climate: Proceedings of the Rome*

Symposium Organized by UNESCO and the World Meteorological Organization, 1961, Arid Zone Research Series No. 20, UNESCO, Paris, 161–181.

[9]IPCC, 2007: *Climate Change 2007.*

[10]For details, see *Epperson v. Arkansas,* 482 U.S. 578 (1987); *McLean v. Arkansas Board of Education,* 529 F. Supp. 1255 (E.D. Ark. 1982); *Edwards v. Arkansas,* 482 U.S. 578 (1987); and *Kitzmiller v. Dover Area School District.*

[11]Michael B. Berkman, Julianna S. Pacheco, and Eric Plutzer, (2008) "Evolution and Creationism in America's Classrooms: A National Portrait," *PLoS Biology* 6, no. 5. (2008): 920–924. See also Brian J. Alters and Craig E. Nelson, (2001) "Teaching Evolution in Higher Education," *Evolution* 56, no. 10 (2001): 1891–1901.

[12]Barbara Forrest, (2007) "Understanding the Intelligent Design Creationist Movement: Its True Nature and Goals," The Center for Inquiry Office of Public Policy website last accessed May 18, 2010, full URL: <http://www.centerforinquiry.net/uploads/attachments/intelligent-design.pdf>; Meyer, Stephen C. (2002) "Teach the Controversy," *Cincinnati Enquirer* website last accessed via the Discovery Institute's Center for Science and Culture on May 18, 2010, full URL: <http://www.discovery.org/a/1134>.

[13]For more in-depth criticism of the methods of intelligent design, see John S. Wilkins and Wesley R. Elsberry, "The Advantages of Theft over Toil: The Design Inference and Arguing from Ignorance," *Biology and Philosophy* 16 (2001): 711–724; Kenneth Miller, (2000) *Finding Darwin's God: A Scientist's Search for Common Ground Between God and Evolution,* Harper Perennial; and Judge Jones's District Court ruling in *Kitzmiller v. Dover Area School District,* 400 F. Supp. 2d 707 (2005).

[14]William Buckland (1837) *Geology and Mineralogy with Considered Reference to Natural Theology,* William Pickering: London 1, pp. 14–15.

[15]Suzanne Sataline (2008) "A Child's Death and a Crisis of Faith," *Wall Street Journal* website last accessed June 10, 2012, full URL: <http://online.wsj.com/article/SB121322824482066211.html>; Associated Press (2008) "Homicide Charges for Parents who prayed as Daughter Died," ABC News website last accessed June 10, 2012, full URL: <http://abcnews.go.com/Health/Story?id=4741392&page=1>; Bill Glauber (2008) "Parents Prayed with Ministry Founder," *Journal Sentinel* website last accessed May 18, 2010, full URL: <http://www.jsonline.com/news/wisconsin/29556439.html>.

[16]Colby Robertson (2009) "Leilani Neumann Takes the Stand is [sic] Husband's Trial," WFXS Fox 55 last accessed on May 18, 2010, full URL: <http://www.myfoxwausau.com/dpp/news/wausau/Leilani_Testifies1008>.

[17]Associated Press (2008) "Homicide Charges for Parents who prayed as Daughter Died," ABC News website last accessed June 10, 2012, full URL: <http://abcnews.go.com/Health/Story?id=4741392&page=1>. Not providing treatment for the child was charges as reckless homicide because Wisconsin law defines "reckless homicide" in terms of "an absence of any care on the part of a person having a duty to perform to avoid inflicting an injury to the personal or property rights of another, by recklessly or wantonly acting or failing to act to avoid doing such injury, evincing such an utter disregard of consequences as to suggest some degree of intent, to cause such injury." *State ex rel. Cornellier v. Black,* 144 Wis. 2d 745, 758, 425 N.W.2d 21, 26 (Ct. App. 1988) (citing *State v. Whatley,* 210 Wis. 157, 245 N.W. 93, 95 (1932)).

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Beginning in Honors: A Handbook by Samuel Schuman (Fourth Edition, 2006, 80pp). Advice on starting a new honors program. Covers budgets, recruiting students and faculty, physical plant, administrative concerns, curriculum design, and descriptions of some model programs.

Fundrai$ing for Honor$: A Handbook by Larry R. Andrews (2009, 160pp). Offers information and advice on raising money for honors, beginning with easy first steps and progressing to more sophisticated and ambitious fundraising activities.

A Handbook for Honors Administrators by Ada Long (1995, 117pp). Everything an honors administrator needs to know, including a description of some models of honors administration.

A Handbook for Honors Programs at Two-Year Colleges by Theresa James (2006, 136pp). A useful handbook for two-year schools contemplating beginning or redesigning their honors program and for four-year schools doing likewise or wanting to increase awareness about two-year programs and articulation agreements. Contains extensive appendices about honors contracts and a comprehensive bibliography on honors education.

The Honors College Phenomenon edited by Peter C. Sederberg (2008, 172pp). This monograph examines the growth of honors colleges since 1990: historical and descriptive characterizations of the trend, alternative models that include determining whether becoming a college is appropriate, and stories of creation and recreation. Leaders whose institutions are contemplating or taking this step as well as those directing established colleges should find these essays valuable.

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Partners in the Parks: Field Guide to an Experiential Program in the National Parks by Joan Digby with reflective essays on theory and practice by student and faculty participants and National Park Service personnel (2010, 272pp). This monograph explores an experiential-learning program that fosters immersion in and stewardship of the national parks. The topics include program designs, group dynamics, philosophical and political issues, photography, wilderness exploration, and assessment.

Place as Text: Approaches to Active Learning edited by Bernice Braid and Ada Long (Second Edition, 2010, 128pp). Updated theory, information, and advice on experiential pedagogies developed within NCHC during the past 35 years, including Honors Semesters and City as Text™, along with suggested adaptations to multiple educational contexts.

Setting the Table for Diversity edited by Lisa L. Coleman and Jonathan D. Kotinek (2010, 288pp). This collection of essays provides definitions of diversity in honors, explores the challenges and opportunities diversity brings to honors education, and depicts the transformative nature of diversity when coupled with equity and inclusion. These essays discuss African American, Latina/o, international, and first-generation students as well as students with disabilities. Other issues include experiential and service learning, the politics of diversity, and the psychological resistance to it. Appendices relating to NCHC member institutions contain diversity statements and a structural diversity survey.

Shatter the Glassy Stare: Implementing Experiential Learning in Higher Education edited by Peter A. Machonis (2008, 160pp). A companion piece to *Place as Text*, focusing on recent, innovative applications of City as Text™ teaching strategies. Chapters on campus as text, local neighborhoods, study abroad, science courses, writing exercises, and philosophical considerations, with practical materials for instituting this pedagogy.

Teaching and Learning in Honors edited by Cheryl L. Fuiks and Larry Clark (2000, 128pp). Presents a variety of perspectives on teaching and learning useful to anyone developing new or renovating established honors curricula.

Journal of the National Collegiate Honors Council (***JNCHC***) is a semi-annual periodical featuring scholarly articles on honors education. Articles may include analyses of trends in teaching methodology, articles on interdisciplinary efforts, discussions of problems common to honors programs, items on the national higher education agenda, and presentations of emergent issues relevant to honors education.

Honors in Practice (***HIP***) is an annual journal that accommodates the need and desire for articles about nuts-and-bolts practices by featuring practical and descriptive essays on topics such as successful honors courses, suggestions for out-of-class experiences, administrative issues, and other topics of interest to honors administrators, faculty, and students.

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