

ACS Interdisciplinary Mini-Grants Interim Report

For Mini-Grants Awarded April 2006, October 2006 & February 2007

Name of Person Submitting Report: Dr. Hopkins, Chair and Associate Professor of
Philosophy

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Institution: Millsaps College

Title of Project: Teaching Scientific Reasoning To Undergraduates Across Disciplines

Date(s) of Project: Fall 2007-May 2008

Amount Awarded: \$4500

1. Original Goals and objectives

- Our original goal was, and remains, to experiment with the most effective means to teach scientific reasoning to a variety of undergraduates drawn from both science and the humanities. While we currently offer a great deal of applied and theoretical science courses, we have found through teaching and conversations with faculty that humanities students typically view science as a difficult hurdle over which they must jump and which they would prefer to criticize as being severely limited in its approach to answering important questions of human origin, behavior, and nature. On the other hand, we have found that science students typically learn how to perform certain tasks in the laboratory and learn a great deal of factual information but often do not learn much about the nature and structure of scientific methodology, reasoning, or epistemology. Our experience then, is that humanist undergraduates learn very little of how science practically works and advances while science students learn very little of how scientific methodology is organized and defended. These education experiences handicap both types of students. Humanities students are ignorant about scientific practice and techniques while science students are ignorant about scientific methodology and creativity.
- Our goal is to improve on this situation by trying a systematic method of teaching scientific epistemology, methodology, and practice. The point is to defragment science education and bring it into holistic view. Science students need to know about the philosophical justification of empiricist epistemology so that they can distinguish what can and what cannot be approached and studied in scientific methodology, while humanities students need to know not only this but also how the actual practices, questions, and creative planning of scientific research begin, proceed, and end. To this end we are creating a holistic and coherent new course which would begin with education in epistemology and empiricism, move toward an explanation of how the

hypothetico-deductive method works in generating information (its strengths and limits), look at famous and groundbreaking experiments, select a few interesting and tricky empirical questions that could be approached through the scientific method, and generate through discussion and criticism a rational and coherent experiment which could get at those questions. The goal is to educate students not only in the background epistemological and methodological problems of science but to culminate in designing an experiment that would use the intellectual critical skills they have learned to focus clearly on producing relevant data.

- Beginning in the spring of 2008, we will run a pilot program staffed by 2 faculty from 2 different disciplines, biology and philosophy. Together we will co-teach a consistent, systematic course in scientific epistemology and methodology, using a jointly produced syllabus with specific shared goals and a shared vocabulary. The course will be targeted to junior and senior science and humanities majors and will teach the epistemological background of empiricism, the grounding of empirical methods in science, critical examples of famous experiments, and would result in a module in experimental design attempting to address specific and complex empirical questions.
- Outcomes: We intend to produce an effective and systematic course that trains students in the epistemology, methodology, and creative practice of science experimentation.

2. Any changes made in goals/objectives to date

- Because our original proposal was partially funded, we altered some of the budgeting. We cut the amount of primary faculty stipend to \$2000 each (though our own institution added some of the original money proposed to subsidize the stipends, I will only talk about the ACS funding here). We dropped the stipends offered to other faculty to let us teach modules on scientific reasoning in their classes, we dropped lunches for discussing issues with other faculty, and we ended up spending much of the remaining money on a variety of textbooks on scientific reasoning from which we culled a collection of reading assignments for our spring class.
- Other than these shifts in budgeting, there were no changes in goals and objectives

3. Activities underway and/or completed to date.

- Research: In the summer of 2007 the two teaching faculty (Hopkins and McGuire) discussed the problems facing our students that were identified in the original proposal. We also discussed goals and outcomes for the course we wanted to create and teach and came up with a general framework for the organization of the course. Our next step was to search textbook databases, online syllabi, and articles on teaching scientific reasoning in order to gather a collection of primary materials we would use for our proposed class. There was a scattered and wide-ranging mix of materials out there for us to use and

we discovered that a great many of the materials were targeted toward elementary school students just learning the basics of science. There were also quite a few resources in the philosophy of science literature, but these were aimed at professional philosophers and sociologists and were more focused on theoretical issues than practical ones of teaching of scientific reasoning. However, we did eventually put together a list of about a dozen works in scientific reasoning and methodology and a list of about 5 on the history of important scientific discoveries that focused on the discoveries themselves rather than the biography of the discoverer. We used funds from the ACS grant to purchase these books and then sat down to the task of perusing them in order to make a selection and create a syllabus. We ended up choosing two books that seemed they would serve us well for the backbone of the course, and decided to take portions from several other books that we would use as supplements. With these resources settled on, we then created the outline of a syllabus.

- Syllabus: We decided to set up our class schedule around an 8 week arrangement, meeting once per week for 2 hours and covering a major topic per week. We limited the class to an enrollment of 12 and decided to meet with the students early in the semester and jointly figure out a time and place to meet (since this is a 2-hour credit course and science lab courses create many scheduling arrangements we decided this would be the best way to get enrollment). While the syllabus is not entirely finalized yet (we are meeting next week to finalize the reading assignments) the outline is completed and is in Appendix A at the end of the this report.
- Enrollment: The course was advertised and quickly filled up during our preregistration in November. We have 12 students and will meet with them early in the spring semester to finalize a meeting time and place based on their needs. The course advertisement is in Appendix B at the end of this report.

4. Any snags or unanticipated delays encountered

- none

5. Budget

Requested Budget:

<i>Expense</i>	<i>Budgeted Amount</i>	<i>Actual</i>
<i>Faculty Stipends</i>	\$5000	See revised budget
• <i>Patrick Hopkins</i>	• \$2500	
• <i>Sarah Lea McGuire</i>	• \$2500	
<i>Educational Meetings (food and materials)</i>	\$500	
<i>Other Faculty Incentive Payments</i>	\$1000 (\$250 ea. for 4)	

TOTAL	\$6500
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Approved and Revised Budget:

<i>Expense</i>	<i>Budgeted Amount</i>	<i>Actual</i>
<i>Faculty Stipends</i>	\$4000	
• <i>Patrick Hopkins</i>	• \$2000	\$2000
• <i>Sarah Lea McGuire</i>	• \$2000	\$2000
<i>Educational Materials (textbooks)</i>	\$500	\$220.18
TOTAL	\$4500	\$4220.18

6. Financial Accounting from receipt of funds through September 30, 2007, showing amounts spent to date and for what it has been spent:

- Please see Approved and Revised Budget (second table) in section 5 above.

7. Appendices:

Appendix A: Outline of Syllabus

Syllabus

Scientific Reasoning

COURSE: SCIENTIFIC REASONING, BIOL 4752-01/PHIL 4752-01
Place and Time TBA, Meeting once a week for 8 weeks
2 credit hours

PURPOSE:

To learn how science works, what it takes for granted, what its methodology is, what it can and cannot do, how it fits into the world of knowledge and belief, what is real science and what is pseudoscience, how to judge and criticize scientific studies, and how to design scientific studies.

This class is designed for science students *and* humanities students. Often, science students learn how to run experiments, how to perform tasks in the laboratory, and learn a great deal of factual information but do not learn about the

nature and structure of scientific methodology, reasoning, or epistemology. They often don't know *why* they doing what they are doing. Humanities students on the other hand often view science as a difficult hurdle filled with technical detail over which they must jump and which they would prefer to criticize as being severely limited in its approach to answering important questions of human origin, behavior, and nature. They often don't know *how* scientists are trying to answer certain questions. This situation handicaps both types of students. Humanities students lack understanding of scientific method and practice and how to judge scientific studies. Science students lack understanding of why a research design is organized the way it is and what its limits are.

Our goal is to improve on this situation by trying a systematic method of teaching scientific epistemology, methodology, and design. In this class we will study the epistemological foundations of scientific method, the history of what has worked and has not worked in science, learn how to assess and critique scientific studies, and learn how to design studies. This class will help scientists be better scientists, humanists be better humanists, and will help everyone become better consumers of scientific information.

ORGANIZATION AND TIME:

This course will be a small class and will be team-taught by Dr. Hopkins of the Philosophy department and Dr. McGuire of the Biology department. The course will meet once a week to discuss readings, analyze studies, hear presentations, and critique student's work. The time of meeting will be decided after students enroll—at a time best for all.

TEXTBOOKS:

1. Understanding Scientific Reasoning by Ronald N. Giere, John Bickle, Robert Mauldin. Wadsworth Publishing; 5th edition (July 13, 2005)
2. The Doctors' Plague: Germs, Childbed Fever, and the Strange Story of Ignac Semmelweis (Great Discoveries), by Sherwin B. Nuland. W.W. Norton & Company (2003)
3. PDF file handouts by email from various sources

SCHEDULE (specific meeting times to be determined by group):

Week 1: What can we know and what is the best way to know it?

- In this section, we will look at the very basis of the empirical method that sciences uses and find out what its limits and implications are. Topics include:
 - The epistemology of empiricism

- The history of empiricism and its critics
- Can we really trust what we see? Is science based on faith in our senses?
- Can science prove anything? Can it disprove anything?
- What are the limits of the empirical method? What can and cannot be studied using empirical means?
- How does empiricism lead to skepticism, pragmatism, and concerns about whether we can ever get to the real world?

Week 2: What is real science and what is fake science?

- In this section we look at the issue of how to distinguish real science from pseudosciences. What is it about an investigative method that makes it scientific? Topics include:
 - Is there a clear distinction between the scientific method and other methods?
 - Why is astrology not a science?
 - Is Freudianism scientific?
 - Is Creationism and Intelligent Design scientific?
 - Is superstring theory in physics scientific?
 - What are the so-called “science wars”?
 - What’s the difference between observation and testability in principle and in practice?

Week 3: What are some important historical cases that show how science works or doesn’t work?

- In this section we look at some famous cases of scientific discovery and some famous cases of things that were believed to be science but ended up disappearing from history as infamous mistakes. The goal is to analyze what worked and what didn’t. Topics include:
 - Semmelweis’ discovery of infection
 - Galileo and the phases of Venus
 - Newton and Halley’s comet
 - The “science” of phlogiston, caloric fluid, and vital spirits
 - Darwin and evolution
 - Mendel and genetics
 - Michelson-Morley and the absent ether
 - Einstein and the solar eclipse

Week 4: How do you test hypotheses and create theories?

- In this section we will look at how hypotheses and then theories are created and tested. What makes for a testable hypothesis? What makes a good theory? Part of the work for this section will be to actually design a study. Topics include:
 - How do you figure out how to test hypotheses?
 - How can you tell which hypothesis is false when an experiment goes badly?

- What are the “virtues” of a good theory?
- Can a good theory be wrong?
- What are testability, simplicity, fruitfulness, parsimony, explanatory power, predictive power, elegance and why do scientists care so much about them?

Week 5: How do you answer questions about statistics and probability?

- In this section we will learn about why probability theory is so important for science and why science almost never seems to “prove” anything but only “suggests” answers (as all scientific studies say). Topics include:
 - Why are things only probable? Why can’t we be sure?
 - How do you judge statistical studies?
 - How do you design statistical studies?
 - Is everything at bottom a statistical study?
 - How can you “lie” with statistics?

Week 6: How do you answer questions about what causes what?

- In this section we will learn about science’s ability to determine if one thing causes another. Why is the notion of “cause” so problematic although it’s the one thing we most want to know about? Topics include:
 - How do you determine if one thing causes another? Can you?
 - How do you design a causal study?
 - Can you know one thing causes another without any idea of how it causes it?
 - Why don’t we know how most of our medicines actually work?
 - How do you judge and assess a causal study?
 - If you can’t make an experiment, can you find one already occurring?

Week 7: How do you criticize and judge experiments?

- In this section we will engage in the very practical activity of judging and criticizing studies and media reports of studies. We will apply all we have learned so far to real studies published in journals and/or reported through popular media in an effort to assess what is good science, bad science, and incomplete science. Topics include:
 - Assessing real scientific studies
 - Learning how scientific studies get published and what sorts of policies and politics go into it
 - Are some journals easy to get published in and others hard? Why?
 - Do media reports of studies get it right or do they spin the results?

Week 8: How Can You Design An Experiment to Answer Really Hard Questions?

- In this section we will learn about designing experiments to test things that are by their very nature difficult to observe. Since the empirical method is all about observation, how can you scientifically study things not observable, such as dark matter, black holes, psychological states? Some

of the most important studies manage to be extremely clever in doing this. How? Part of the work in this section will be to design a real study about such difficult issues. Topics include:

- The problem of unobservables
- Beliefs, ideas, emotions, all psychological states are invisible to observers so how can they be studied?
- Animal cognition
- Black holes and dark matter
- Aliens, angels, fairies
- Parapsychology as a science?
- Can religious ideas be studied scientifically?

Appendix B: Course Advertisements

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scientific reasoning
phil 4752-01
dr. hopkins
meets first half of semester, time tba

2 credit hours

To learn how science works, what it takes for granted, what its methodology is, what it can and cannot do, how it fits into the world of knowledge and belief, what is real science and what is pseudoscience, how to judge and criticize scientific studies, and how to design scientific studies.

This class is designed for science students and humanities students. Science students often learn how to run experiments but don't know why they are doing what they are doing. Humanities students often don't know how science tries to answer questions. If you want to know what to make of black holes, dark matter, superstrings, astrology, evolution, alchemy, animal consciousness, dinosaurs, and psychic powers, take the class



Scientific Reasoning

TIME: Once a week for 2 hours for 8 weeks, first half of the semester, specific time TBA (will decide time with students)

WHO: Team taught by dr. Hopkins of philosophy and Dr. McGuire of biology

PURPOSE: To learn how science works, what it takes for granted, what its methodology is, what it can and cannot do, how it fits into the world of knowledge and belief, what is real science and what is pseudoscience, how to judge and criticize scientific studies, and how to design scientific studies.

Week one: what can we know and what is the best way to know it?

Week two: what is real science and what is fake science?

Week three: historical cases showing good science and bad science

Week four: how do you test hypotheses and create theories?

Week five: how do you use statistics and probability?

Week six: how can you tell what causes what?

Week seven: how to criticize and judge experiments

Week eight: how to design experiments to answer really hard questions

WHO SHOULD TAKE IT: This class is designed for science students and humanities students. Science students often learn how to run experiments but don't know *why* they are doing what they are doing. Humanities students often don't know *how* science tries to answer questions. In this class, we'll learn the *why* and the *how*. If you are interested in how science works, how science should work, how to design and judge experiments and how to determine what science can and can't do, take the class. If you want to know what to make of black holes, dark matter, superstrings, astrology, evolution, alchemy, animal consciousness, dinosaurs, and psychic powers, take the class.

