ACS Interdisciplinary Mini-Grants

Final 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 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 was to improve on this situation by trying a systematic method of teaching scientific epistemology, methodology, and practice. The point was 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 created a holistic and coherent new course on scientific methodology and scientific literacy and taught the course as an 8-week special

class cross-listed in the Philosophy and Biology departments, recruiting twelve students evenly divided from both the humanities and sciences. This course is described in detail in section 3.

2. Revised goals and objectives

- 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. Meeting Goals and Objectives

- The course we designed to meet our goals was team-taught by Hopkins (Philosophy) and McGuire (Biology) who were present at each and contributed jointly to each class meeting.
- We researched the course in the following way: 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.

- We organized and taught the course in the following way:
    i. We began the course with education in epistemology and empiricism, explained how the hypothetico-deductive method works in generating information, explaining the history of empiricism and how it has been criticized, looking at the pragmatic defenses of empiricism, and discussing the strengths and limits of the empirical method;
    ii. We then moved to a discussion of the famous “demarcation problem” in the philosophy science, which is the question of what counts as real science and what counts as pseudoscience, including the issues of testability, falsifiability, and predictive success, then looking at specific cases where the scientific nature of an investigation has been called into question, including astrology, psychic research, creationism, Marxism, Freudianism, and superstring theory. As an exercise, students were required to analyze 4 hypotheses explaining “near-death” experiences and were required to explain in writing whether the hypotheses were open to scientific testing in practice or in principle (see appendix A);
    iii. We then looked at some important historical cases in scientific explanation with a goal toward understanding what sorts of explanations worked what sorts did not and why, including Semmelweiss’ discovery of infection (which was our primary focus, including well-known philosophical analyses of the famous maternity ward experiments), Galileo and the phases of Venus, Newton and Halley’s comet, the concepts of phlogiston, caloric fluid, and vital spirits, Darwin and evolution, Mendel and genetics, Einstein and the solar eclipse;
    iv. We then examined the theoretical and practical issues of generating hypotheses and how to set up tests to explore those hypotheses, with an emphasis on learning the virtues of a good theory;
    v. We then spent time on understanding statistical concepts and methods, focusing on why statistics is necessary to science and why in large part only statistical information can be produced, and getting students to truly understand (and not merely employ) important statistical ideas such as averages, margins of error, degrees of freedom, normal distributions, standard deviations, significance levels, and representative samples. We also spent a good bit of time looking at how instruments and surveys are created and what sorts of fallacies can lead them to produce biased information;
    vi. We then moved from statistical studies to causal studies (pointing out that “causal” studies still employ statistical methods and our causal claims are still in large part statistical), paying special attention to analyzing and criticizing causal studies, how to appraise “naturally” occurring causal studies (cause-to-effect and effect-to-cause) and to recognize that often we can make causal claims even when we do not know the mechanism by which the cause works (as in the case of many medicines);

vii. We then focused on helping students apply what they had learned so far to the task of criticizing actual scientific studies, which we selected to range from studies that examined directly observable entities (such as genes) to studies that examined difficult to assess states (such as self-reported happiness and satisfaction levels in human subjects) to studies that tried to examine unobservables (such as mental states of animals);

viii. We concluded with an exercise in scientific methodology literacy in which each student had to find a news media report of the results of some scientific study, then had to analyze how the media described the results of the study, then had to find the original study and compare how the media report represented the study to what the study could actually claim. The purpose of this was to get students to understand that media often inaccurately describe scientific studies and that to know what the study actually is justified in showing, they need to know certain details about the study itself. Students were then required to present the conclusions of their analysis to the class.

4. Assessment

- We discovered during our research that there is no widely used and generally settled upon standardized test for assessing knowledge of scientific methodology, so we decided to base assessment on our own appraisal of students' final ability to criticize the structure of a scientific study, determine what one could and could not determine from the results of the study, and to translate this information into a public presentation. We also based assessments on student course evaluations and student feedback.
- We were largely encouraged by the results of the course. In our assessment of students' abilities to analyze, criticize, and describe a scientific study, we were pleased to see that approximately 4/5ths of the class were able to do so in clear and coherent ways. They were able to understand the organization of a study and determine what its limitations were; they were able to recognize when media reports of studies made inaccurate claims; they were able to understand statistical conclusions of studies; they were able to present their assessments of studies to the class at large in informative and clear ways.
- We were also largely encouraged by student feedback on the course. Humanities students in particular were complimentary and said that the course helped them understand science and its practices in ways they had never come across in required science courses. They felt they had a clearer and more precise understanding of science and felt to some extent empowered because they could now interpret basic statistical information and study design. Science majors were a bit less enthusiastic, but we think this was partly due to the fact that so many of the science majors were pre-med and interpreted virtually every course they took and every activity they engaged in in terms of helping them get into medical school. They were less excited about this course then, because it didn't seem to be something they could clearly point to

that would increase their chances of acceptance. They did learn, however, and were quick to say that they were especially intrigued by looking at media reports of studies and discovering how information was disseminated to the public.

- As for formal student course evaluations, the overall mean rating of the course was a 5.3 out of 7, with 4 being defined as average and 5 defined as above average. The mean rating of the instructors was a 5.8, with 5 defined as above average and 6 defined as excellent. Mean scores on subquestions were all ranked at 5.9 or above, with particularly high scores (6.5-7.0) on 10 out of 19 subquestions (copy of evaluations attached). While these scores were not as high as some the instructors have had in other courses, we were pleased overall, though we recognize that we will need to improve our efforts to show the importance of the course content and its usefulness when we teach the class again.

5. Lessons Learned

- First, we learned that this was a useful class and that it did meet a need, especially for humanities students seeking to understand science and for science students in helping to understand how the media reports on studies. Our experience that science courses do not quite provide all that students' need was validated. Science courses largely provide content and technique but do not provide the intellectual background for understand how science works, what the epistemological limits of the scientific method are, and perhaps most importantly, how to interpret and criticize scientific information filtered through the media. In this sense, we have had our conviction that scientific literacy is important and that students need to become educated consumers of scientific information. In that regard, our assignment analyzing and comparing media reports of studies with the actual studies themselves was very useful and we need to do more of that in the future. In fact, this concept of becoming an educated science consumer may have formed the central framework for what we think is valuable about the course and might serve as a model for what all students should learn.
- Second, we learned that there was still a difference between students who are science majors and those who are humanities majors. The science majors in general saw less use for the course than the humanities majors. Our supposition however is that this had less to do with the science students already knowing the information and more to do with the fact that most of the science majors were premed and interpreted the value of all they did in terms of how it might help them get into medical school. We suspect that with more students actually interested in science as a career, we would find greater satisfaction with the course. In any case, the emphasis on analyzing and criticizing studies was useful for the science majors as well as the humanities majors and we would not make any radical changes to the course.
- Third, one thing we simply did not have the time for but which we would like to add to the course if we teach it again is to have students not only criticize

studies but to design a few studies of their own—not in great technical details but in enough detail to make sure they understood the major concepts of control groups, isolation of variables, statistical power, conceptual clarity, and bias reduction. We think this would add to students' understanding. We would also increase the number of assignments that dealt with reading and critiquing media reports of studies so that students got an even broader sense of how to do this and hopefully with more experience doing so, internalized the skills used to critique such information.

- Fourth, in general we learned that this class is needed and should be offered again, possible even becoming a model for a liberal arts education. It ended up addressing exactly the problems we initially indicated and deserves further development.

6. Follow Up

- While we do not have immediate plans to teach this course again soon, we think the course was very successful and with a few changes would be even more so. We also think it is very close to what students in general need in order to become educated and critical consumers of scientific information—a broad educational goal important for anyone living in an age inundated with information that at least purports to be backed up by scientifically gathered and analyzed data.
- As such, we would like to revamp the course to be a semester-long class and target it to two different groups, depending on the needs and appraisal of our core curriculum. First, we would like to try teaching this course as a double session of our freshmen seminar. This would involved team-teaching a group of 30-40 freshmen basic college reading, writing, and reasoning skills, but would focus on being literate and critical consumers of scientific information (as you can see, a major recurring theme of our experience). Second, and perhaps alternatively, we would like to teach this course as an option for our required core 9 course, which is a required sequence course for all students that must be either a math, natural science, or computer science class (the student's choice, given that they have already been required to take a natural science and lab class and a social science class). We would hope that this class would be particularly attractive to none-science majors and would perhaps be more useful to them practically than some courses they currently end up taking. Given our schedules (we taught this class as an overload this semester) and college requirements to specify course schedules early, we would not be able to teach either class until the fall of 2009 but are seriously going to try to make it work.

7. Budget

Requested Budget:

Expense	*Budgeted Amount*	*Actual*
Faculty Stipends	$5000	See revised budget
• ***Patrick Hopkins***	• $2500	
• ***Sarah Lea McGuire***	• $2500	
Educational Meetings (food and materials)	$500	
Other Faculty Incentive Payments	$1000 ($250 ea. for 4)	
TOTAL	$6500	

Approved and Revised Budget:

Expense	*Budgeted Amount*	*Actual*
Faculty Stipends	$4000	
• ***Patrick Hopkins***	• $2000	$2000
• ***Sarah Lea McGuire***	• $2000	$2000
Educational Materials (textbooks)	$500	$220.18
Education Materials (science DVDs)	$0	$279.82*
TOTAL	$4500	$4500

* Because we used less money than we planned for textbook educational materials, we elected to spend the remaining funds on educational DVDs that include historical material on famous experiments and famous scientists, current issues in science and politics, the debate over intelligent design as a science, and specials about current issues in science. These DVDs were primarily documentaries from PBS, NOVA, Discovery Channel, and 60 Minutes. These DVDs will be very useful for future iterations of this course.

8. Permission to share results

We, Patrick D. Hopkins and Sara Lea McGuire, give ACS permission to post our original proposal and a summary of our work on the ACS Interdisciplinary website.

9. Appendices:

Appendix A: Science and Pseudoscience assignment

Assignment #1

Read exercise 4.6 on page 108 of the Giere textbook. In this reading, four explanations of the phenomenon of NDEs are described:

1. Moody: the existence of a nonmaterial soul which survives death best explains
2. Sagan: recollection of the birth experience best explains
3. Stress: abnormal brain chemistry brought on by stress best explains
4. Blackmore: NDEs are false memories of what happened best explains

Thinking about what we read with Lipton, Hempel, and the Semmelweiss case on making predictions and explaining contrasts, explain what would count as evidence *against* and what would count as evidence *for* each of these four hypotheses. That is, what sort of observational predictions would each hypothesis make and how might you go about testing those predictions? In terms of testability, are all the hypotheses equally valuable?

Please write this exercise up in a Word document, email it to Dr. Hopkins and Dr. McGuire by Wednesday at noon and bring a printed copy with you to our next class.

Appendix B: Scientific Literacy and Media Analysis Assignment

SCIENTIFIC REASONING ASSIGNMENT

You are to locate a media report of a scientific study and analyze it, comparing it to the actual scientific study to see how fairly and accurately the media report treated it.

First, locate some media report of a scientific study. This could be any kind of study as long as it was supposedly carried out scientifically. It could be a medical study, a survey or poll, a physics experiment—anything that is described as using scientific methodology. The report could be from a magazine, a newspaper, a television news show, an online newssite, or even some advocacy organization’s announcement or press release. The main goal is to find a case where someone has summarized and reported on someone else’s study. Stay away from popular science magazines however, such as Discover or Scientific American. Those articles will be too long. Newspapers and online newssites are probably the best.

Second, you are to locate the original source of the media report. This may be an actual published paper in a scientific journal; it may be the proceedings from a scientific conference; it may be some sort of report from a scientific institution. The important thing is that it is the source of the information in the media report. It can be somewhat difficult to find such materials so give yourself plenty of time. In general, it may be best to find a media report from a year or two ago rather than a brand new report, because sometimes the scientific study isn’t published yet and the reporter got their material from listening to a conference presentation. Be prepared to search for the original source. Pay close attention to the media report you find and check to see if is says “a paper appearing in Nature last week” or something like that. That means you can find it easily.

Third, when you have located these materials, you will analyze the media report and will include this in your presentation. What that means is that you are to outline the information in the report, describe what the report says, what impression it gives, and whether or not it gives much actual data. For example, does it say that a possible treatment for cancer has been found? Global warming has been proven? That people who take Vioxx have heart attacks? That crime has decreased or drug use gone up or beliefs about politics changed? Whatever it says, explain how it comes across. What would a casual reading of the report suggest that scientists had discovered? What emotion laden words or vagueness or exaggeration seem to be used? Also make certain to note what information is lacking in order to understand the study. Was the type of experiment noted? Or the sample size or the error margins (depending on what kind of study it was)? What more would you need to know in order to assess the importance of the study?

Fourth, you will analyze the actual study. What the study actually say? What specific claims does it make? Using the information we are studying about sample size, confidence levels, statistical significance, margins of error, sample representativeness, understanding dependent and independent variables, causation, controlled experiments, etc., explain what the study shows and how expansive or limited the conclusion actually is. The purpose of this analysis is not such much to show problems with the study (though you should do that if you find them), but rather to clearly describe what actual limited conclusion the study provides evidence for.

Fifth, compare the media report to the actual study. Was the report accurate? Was it overblown? Did it suggest something that the study didn't find? Did it not report useful information, like sample size or type of experiment or margin of error (or whatever)? In short, explain whether the report was a good and accurate description of the study or whether it wasn't. Explain exactly why the report is good or bad, or some mixture.

Sixth, you will present all this information to the class in a 5-10 minute presentation. You are welcome to talk informally rather than read anything, but you should have notes so you can make sure to cover all the relevant analysis you did.

Finally, in no more than two pages, summarize what you found (according to the organization described above) in a simple, straightforward report and email this report to each of us.

Appendix C: Course Syllabus

Syllabus

Scientific Reasoning

COURSE: SCIENTIFIC REASONING, BIOL 4752-01/PHIL 4752-01
CC 22; Wednesdays 6-8 pm
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:

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.

TEXTBOOKS:

1. [SR] Understanding Scientific Reasoning by Ronald N. Giere, John Bickle, Robert Mauldin. Wadsworth Publishing; 5 edition (July 13, 2005)
2. [DP] 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. [H] PDF file handouts by email from various sources

SCHEDULE:

<u>Week 1 (Jan 16): What can we know and what is the best way to know it?</u>

- No reading
- 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?

<u>Week 2 (Jan 23): What is real science and what is fake science?</u>

- Readings: Popper [H], Schick ch.7 [H], Duhem [H], Woit [H], Giere ch. 4 [SR]
- 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?

<u>Week 3 (Jan 30): What are some important historical cases that show how science works or doesn’t work?</u>

- Readings: Giere ch. 3 [SR], Nuland [DP], Hempel [H], Lipton [H]

- 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 and how the method worked if it did. Topics include:
    - Semmelweiss' 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

<u>Week 4 (Feb 6): How do you test hypotheses and create theories?</u>

- Readings: Giere ch2 [SR]
- 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?

<u>Week 5 (Feb 13): How do you answer questions about statistics and probability?</u>

- Readings: Norton chs 9, 10 [H]; Giere chs 5,6 [SR]
- 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?

<u>Week 6 (Feb 20): How do you answer questions about what causes what?</u>

- Readings: Giere chs 7,8 [SR]
- 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?

<u>Week 7 (Feb 27): How do you criticize and judge experiments?</u>

- Readings: 5 studies [H]
- 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
  - Issue of studying non-observables
  - 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?

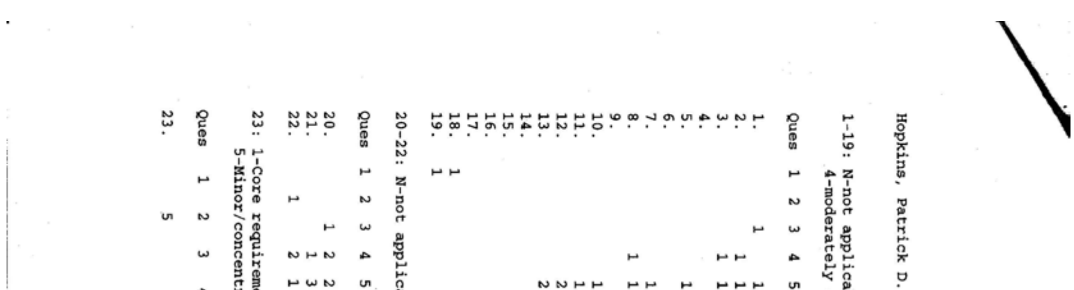
<u>Week 8 (March 5): Students criticize studies and media reports</u>

- Readings: none
- Students will present their critique of a media report and the original study on which the report is based. Instructions will be given later.

ASSIGNMENTS:

25% Participation
25% Presentation
30% Paper (Write-up of presentation)
10% Short paper on pseudoscience
10% Statistics assignment

Appendix D: Student Course Evaluations


Hopkins, Patrick D.
1-19: N-not applica
4-moderately
20-22: N-not applic
23: 1-Core requirem
5-Minor/concent

Appendix E: Course Advertisements

S

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

Scienti[illegible] 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.