Inference in Science – CDLTI workshop synopsis and individual reports.
Spring 2013

In this workshop, we explored processes by which science produces understanding of the world, and how scientific understanding, and assumptions about scientific understanding, influence the role of science in society.

Science holds a privileged place in our society. Knowledge that can claim to be 'scientific' is explicitly valued by governments, many segments of the private sector, and by large portions of the public. This is rooted in the belief that something often referred to as 'the scientific method' exists and that it provides a uniquely robust means of building understanding of the material world. This belief plays an important role in our society, but this belief and the assumptions behind it are not widely discussed or examined. Even most scientists devote little if any time to critical examination of the 'scientific method.' There is certainly almost no discussion of these topics between scientific disciplines. Further, many of the academics who think most about scientific inference as a phenomenon are outside of science, and communication between those who study science and those who practice science is typically equally rare. This workshop brought together scientists and those outside of science concerned with problems of inference to discuss science as a mode of understanding the world and as an institution in society.

We identified a series of topics of interest to participants, and individuals volunteered to provide readings for topics. After the initial planning meeting, participants discussed readings and their potential implications for two hours at each of seven meetings. The topics and readings were as follows:

Jan 18. Meeting to select topics and to assign responsibility for topics.

Feb 1. Is it science?

J. Worral. 2002. Philosophy of science: classic debates, standard problems, future prospects. Ch. 3 *in* P. Machamer and M. Silberstein eds. The Blackwell Guide to the Philosophy of Science.

J. Woodward. 2002. Explanation. Ch. 3 *in* P. Machamer and M. Silberstein eds. The Blackwell Guide to the Philosophy of Science.

J. Bogen. Experiment and observation. Ch. 7 *in* P. Machamer and M. Silberstein eds. The Blackwell Guide to the Philosophy of Science.

Feb 8. Methods of inference (statistics – frequentists vs. Bayesians)

Nicholas J. Gotelli and Aaron M. Ellison. 2004. Three Frameworks for Statistical Analysis Ch. 5 in A Primer Of Ecological Statistics. Sinauer Associates

E. T. Jaynes. 1995. Preface *in* Probability theory: the logic of science.

Gelman, A. 2008. Objections to Bayesian statistics. Bayesian Analyses. 3: 445-450.

Bernardo, J. 2008. Comment on article by Gelman. 3: 451-454.

Kadane, J. B. 2008. Comment on article by Gelman. 3: 455-458

Senn, S. 2008. Comment on article by Gelman. 3: 459-462.

Wasserman, L. 2008. Comment on article by Gelman. 3: 463-466.

Gelman, A. 2008. Rejoinder. Bayesian Analyses. 3: 467-478.

Feb 22. Different faces of science:

Physics:

The ATLAS Collaboration. 2012. Observation of a new particle in the search for the standard model Higgs Boson with the ATLAS detector at the LHC. Physics Letters B.

S. Perlmutter and B. P. Schmidt. 2003. Measuring cosmology with Supernovae.

Molecular biology:

L. Pauling, H. A. Itano, S. J. Singer, and I. C. Wells. 1949. Sickle cell anemia, a molecular disease. Science 110: 543-548.

M. Meselson and F. W. Stahl. 1958. The replication of DNA in Escherichia coli. PNAS.44: 671-682.

D. M. Vernon and H. J. Bohnert. 1992. A novel methyl transferase induced by osmotic stress in the facultative halophyte *Mesembryanthemum crystallinum*. The EMBO Journal. 11: 2077-2085.

Evolutionary biology and ecology

O. Pellmyr and C. Huth. 1994. Evolutionary stability of mutualism between yuccas and yucca moths. Nature 372:257-260.

K. N. Suding et al. 2005. Functional- and abundance-based mechanisms explain diversity loss due to N fertilization. PNAS 102: 4387–4392

April 12. Historical science:

Cosmology: The study of the universe: http://map.gsfc.nasa.gov/universe/

The true science of parallel universes: http://www.youtube.com/watch?v=Ywn2Lz5zmYg&feature=youtu.be

Sean Carroll blog: Philosophy and Cosmology: http://www.preposterousuniverse.com/blog/2009/09/20/philosophy-and-cosmology-slow-live-blogging/

G. J. Retallack. 2012. Ediacaran life on land. Nature. 493: 89-92.

S. Xiao. 2012. Muddying the waters. Nature. 493: 28-29

L. P. Knauth. 2012. Not all at sea. Nature. 493: 29

I. P. F. Owens, P. M. Bennett, and P. H. Harvey. 1999. Species richness among birds: body size, life-history, sexual selection, or ecology? Proceedings: Biological Sciences. 266: 933-939.

April 19. Incentives, management structure:

About CERN: http://home.web.cern.ch/about

CERN Code of Conduct. 2010. http://cds.cern.ch/record/1273755/files/Codeofconduct.pdf

K. Holly. 2009. CERN's collaborative management model. Bloomberg Buisnessweek. http://www.businessweek.com/innovate/content/may2009/id20090520_115971.htm

US National Science Foundation (merit review process, strategic plan, etc.) http://www.nsf.gov/about/glance.jsp http://www.nsf.gov/bfa/dias/policy/merit_review/index.jsp http://www.nsf.gov/news/strategicplan/nsfstrategicplan_2011_2016.pdf

European Research Council. Mission: http://erc.europa.eu/mission

Sean Carroll blog: Guest Post: Juan Collar on Dark Matter Detection: http://www.preposterousuniverse.com/blog/2008/04/21/guest-post-juan-collar-on-dark-matter-detection/

Parker, T. H. 2013. What do we really know about the signalling role of plumage colour in blue tits? A case study of impediments to progress in evolutionary biology. Biological Reviews. 88 (3) In press.

May 3. Law/ Enviro sci/public policy:

Daubert v. Merrell Dow Pharmaceuticals, Inc. 1993. Supreme Court Ruling, Opinion of the Court, Dissenting Opinion.

J. L. Mnookin. Expert evidence, partisanship, and epistemic competence. Public Law & Legal Theory Research Paper Series. No. 08-12. Brooklyn Law Review 73.2: 587-611.

Three speeches by Michael Crichton. scienceandpublicpolicy.org/commentaries_essays/crichton_three_speech.html

May 13. Continued discussion of incentives. Overall conclusions.

Because we come from divergent backgrounds, we each derived unique lessons from this workshop. However, certain themes emerged. Many of us began the workshop with a definition of science that subsequently proved incomplete. We became aware of the shortcomings of our definitions, and of some the challenges that stand in the way of a unified definition. Those of us who teach science are likely to devote more thought and more time to helping our students understand what makes science distinct. Those of us from other disciplines can also carry our new understanding of the definition of science into our teaching. This may involve drawing parallels between the process of science and ways of knowing in other fields, or it may involve more sophisticated interpretation of science in broader contexts. Some of us involved in statistical analysis of data grew in our awareness and appreciation of some serious pitfalls in this realm. As individuals, we have begun raising our students' awareness of statistical mistakes that often lead to faulty conclusions. Many of us gained a more sophisticated appreciation for the obstacles to applying science in policy and legal issues. Those of us who teach classes in which issues of science and policy arise now have more examples available and we can hopefully bring our students to a better understanding of these obstacles. As at least one participant noted, we could have devoted considerably more time to understanding science in society. A future workshop on that theme would be of great interest.

Tim Parker (Biology)

a) This workshop fostered thoughtful and challenging discussions regarding the definitions, processes, and cultural contexts of science. I came away from this semester with a more sophisticated understanding of the difficulty of defining science. Although I grew to realize that the definition I had understood prior to the workshop is imperfect, I also grew confident that I could adopt a working definition that is effective in my field and useful to students. We discussed paths to inference in several disparate scientific disciplines and explanations for different rates of progress in these fields. These are rare topics of discussion among scientists and they will bring more critical perspective to teaching in our own disciplines. Finally, scientists are often accustomed to working in a bubble and ignoring the cultural context of their work. We discussed the difficulties of bringing science into the legal and political realms and again grappled with questions that lack easy answers.

b) The Inference in Science workshop will directly influence my teaching in multiple ways. Most important, in my ecology class, students read scientific papers throughout the semester and must identify the scope of the inference that can be drawn from the results presented in each paper. Students find this among the most challenging aspects of the course. My more sophisticated understanding, not only of the definitions of science, but also of the modes of progress in other sciences, will now inform how I guide students through the process of interpreting scientific literature. Definitions of science, limits of science, and application of science are important themes in other classes I teach, including Natural History and Ecology, Introduction to Environmental Studies, and Biodiversity. The latter two are explicitly interdisciplinary and I am always seeking to broaden the perspective I bring to them. The workshop led me to a more sophisticated understanding of the definitions of science and the challenges of applying science in other realms, and this will directly impact my interdisciplinary classes.

c) This is the second CDLTI workshop in which I have participated. I found both workshops intellectually stimulating. They both fostered connections across disciplines and gave me wonderful ideas for teaching. However, in both cases, it was challenging to invest sufficient time in the workshop while also allocating enough time to my teaching. Especially in a semester such as this one in which I was dramatically revising a class, doing such a workshop was probably unwise. I worry that new faculty, tempted by the fruit of such a workshop, could suffer from the reduced investment in their teaching.

Moira Gresham (Physics)

(a) From my perspective, the workshop was successful. I came to the workshop hoping to better understand methods and modes of inference used in other sciences and to better understand what makes science "science". I also hoped to better understand what distinguishes my field from other fields of science. These goals were met. In the case of understanding what makes science "science", I now know that I don't really know. I can identify hallmarks of good science, but it's rather difficult to provide a tight characterization.

(b) Our look at case studies especially in biology and geology have motivated me to spend more time searching out and highlighting examples of physics used in other branches of science, especially in my general physics class. Indeed I will use examples from some of the very case studies we examined. I will also feel comfortable approaching the other scientists who participated in the workshop for advice on this matter.

I also hope to incorporate some of my better (or at least more nuanced) understanding of what makes science special, and what makes for "good" science, in introductory physics laboratories. It has become clear to me especially in introductory laboratory sections that---even though the majority of the students in these classes are science majors---many students don't seem to have an appreciation of scientific method or for the importance of careful inquiry. I'd like to respond by incorporating some big picture, context-setting discussions about science and physics in future laboratory meetings. I will also seek advice from Prof. Parker on this matter since I learned that he has incorporated such discussions into some of his introductory courses.

(c) The organization and design of the workshop worked fine as far as I'm concerned.

I had a lot of fun in the workshop; the opportunity it afforded---to have substantive intellectual engagement with colleagues outside my discipline---is exactly the kind of opportunity to which I had hoped to gain access in coming to Whitman. Thanks for the opportunity!

Christopher Leise (English)

This was a highly successful workshop that focused on two very specific considerations: first, we engaged with the sticky definitional wicket of that which comprises the domain of scientific inquiry (and what doesn't); the second involved how differing scientific specialties identified evidence and built conclusions from the collected data.

I can happily report that I left with a less-clear idea of what constitutes science (and what sets science apart from other methods of investigating the world) than when I entered this workshop, which means I've thought myself to a considered position of non-understanding. This, in and of itself, means that I've at least thought about the problem in a rigorous and specific way, which I've not done before. It also got me to read Thomas Kuhn's The Structure of Scientific Revolutions, which I'd meant to since grad school, but had not yet.

I also saw clear parallels between what I do in literary studies and how "historical sciences" collect and deploy evidence. I'm certain this latter insight will make me a much more effective instructor of introductory Humanities courses, where I often talk to groups with widely diverse interests. It also got me thinking about courses about I might offer in the future, either on literature about science (like Richard Powers and Rivka Galchen) or, perhaps more interestingly, literature that reflects the increasing tendency to treat scientific knowledges as privileged modes of knowing the world in and after modernism. The rise of science as a type of master discourse (see Lyotard)—which affects both literary content as well as literary style (see Steven Millhauser, Ben Marcus, Thomas Pynchon, u.s.w.)—will become a mainstay of my "American Literature, 1920 to the Present" course.

Finally, I've written a bit about systems theory in the past; this helped me refresh some of what I know about first- and second-order systems theory, which is indispensible in understanding postmodern fiction heavyweights like Gaddis, Pynchon, Gass, and Powers.

Kelly McConville (Mathematics)

From day one, I was struck by how difficult it is to talk about science. Science is a very vast field and each branch and sub-branch comes with its own terminology. However, I think the struggle to discuss scientific ideas across disciplines was one of my favorite parts of the workshop. In particular, for one session we discussed statistical inference and I was supposed to help guide that discussion. I left the session realizing how difficult it is to talk about statistical and probabilistic ideas without getting steeped in jargon. The session motivated me to think more deeply about how statisticians interact with scientists and how we could make those interactions more meaningful by breaking down some of the scary notation and theoretical constructions.

Statisticians develop methodology to analyze and understand data. Statisticians also spend time constructing sampling designs to allow for the proper conclusions to be made from data. Therefore, statisticians believe very deeply in the scientific process. However, I think what statisticians often don't do is talk to scientists. I sometimes worry that statisticians are developing methods that only work in the "perfect world" while scientists must conduct their research in the real world. I believe more conservations about how scientific inference is conducted, like the conservations we had in this workshop, will show statisticians where the true methodology needs lie. Therefore, I felt the conversations about the work done by each scientist in the group was very beneficial to me as a researcher.

This workshop forced me to think much more about how the statistical methods I teach my students play out in answering scientific questions. During one of the group discussions, someone mentioned the article "Why Most Published Research Findings are False" by John Ioannidis, which prompted me to read the article. Ioannidis discusses some of the sad realties that scientific research faces, such as prejudices in the field and publication bias, and he makes some interesting statistical arguments for why many claimed results are untrue. On the last day of my Math 350 (Mathematical Modeling and Numerical Analysis) class, the students and I discussed Ioannidis's article along with "The Truth Wears Off: Is There Something Wrong with the Scientific Method?" The students seemed to really enjoy discussing the use of statistical methods in scientific inference and the problems that arise. I hope to incorporate more discussions of scientific inference articles into my data analysis classes.

Additionally, the workshop showed me that part of training my students to be good statisticians show involve conversations about research and data analysis between my students and their peers. Therefore, also in Math 350, I gave the students an assignment to attend the Undergraduate Research Conference and talk stats with at least three presenters. The students had to turn in a write-up about their interactions. From their write-ups, it seemed that they were able to engage the conference participants in good discussions about statistics and how it can be used to conduct research.

Dan Vernon (Biology)

A. The workshop did a good job of highlighting differences in scientific questions, how they are framed, and the types of evidence needed to test them in different scientific disciplines (e.g., "big" physics, historical science, and genetics). Discussions made participants consider exactly what constitutes real science, and what can be considered rigorous evidence for (or, more importantly, against) an hypothesis. While comparisons between scientific disciplines may not at first seem to fit the definition of "cross-disciplinary", discussions in this workshop underscored big differences in how science is carried out in different fields, how it is truly defined, and how it contrasts with aspects of the humanities and even math. In addition, the workshop encouraged discussion of aspects of science of interest to social scientists and those in the humanities, such as questions about the (sometimes) privileged place science has in social policy and its influence in law.

B. This workshop could contribute to my teaching both within the biology department and in the Biology 125 course (Genes and Genetic Engineering), which is taken mainly by students from the humanities, arts and Division I. In my biology courses, ideas about framing hypotheses and the means by which they are tested will be included in my Genetics and Molecular Biology lecture courses and laboratories. There is already a good deal of experimental coverage in these classes, and the material from this workshop will enrich coverage of that material. Ideas discussed in this workshop will contribute to the non-majors' course, where such issues as the definition of science, the nature of the scientific method, and the importance of hypotheses, testable predictions, and experimental evidence are themes that run throughout the semester.

C. The topic for this workshop- scientific inference- lent itself to discussion/comparison of different philosophies within the sciences. This in my view was still "cross disciplinary"- in fact it underscored the heterogeneity of questions, approaches and ways of thinking within "the sciences" themselves. However, in my view some of the more interesting questions dealt with science's influence outside the sciences, and how others viewed science and scientific thinking. If we could do the workshop over, I'd suggest reorganizing it to spend more time on these sorts of broadly-interdisciplinary topics rather than on deeper philosophical comparisons between fields within the sciences.

Patrick Belanger (Rhetoric)

How the course encouraged creative inquiry into cross-disciplinary teaching and learning:
The Spring 2013 cross-disciplinary workshop on scientific inference (led by Tim Parker) expanded my understanding of the practice and its associated politics. By seeking to demonstrate the rhetorical motivation of attitude and belief, my approach is embedded in the interpretive tradition. However, in concert with the perspective of critical realism, I argue for differentiation between better and worse, more and less accurate, discursive approximations of the material world. Within the sphere of science, the ultimate communicative aim appears to be construction of a narrative that closely approximates a natural or historical process. Towards this end, integration of empirical rigor with reflexive practice allows for the determination of a hierarchy of interpretations along an axis of differential probability while concurrently maintaining awareness of the influences enacted by ideological frameworks. This course confirmed my belief that it is possible to comparatively adjudicate truth claims with respect to rationales and evidentiary bases.

The structure of our meetings was well orchestrated. Each participant led a session discussion and provided an overview of his/her understanding of the concept of scientific inference (and outlined potential concerns regarding its application). This provided an invaluable opportunity to learn how individuals from multiple disciplines engage the idea and practice.

How I will incorporate the results into my instruction:
In future teaching I will emphasize the challenges posed to public deliberations by the scientific norm of communicative caution. Assuming that credible scientific voices are integral to informed discussion and prudent public policy in the arena of environmental science, we will inquire: how can such voices prevail when others are willing to employ the full range of rhetorical tactics? The physical world, both as process and discursive reconstruction, has a fundamental impact on lived experience. My teaching will thus foreground the merits of science literacy and advocacy, and explore means by which high-quality scientific communication is both facilitated and hindered.

Tim Doyle (General Studies)

(a) I count the Inference workshop as a success. I will move forward with a substantially increased repertoire of scientific examples to inform my teaching and research. I forged intellectual relationships with several members of the group, which may lead to collaboration in scholarship or teaching.

(b) I won't hesitate to approach the other workshop participants during the process of lesson planning and course development to deepen my understanding of particular examples of inference in science. I will especially seek out Profs. Vernon, Parker, and Bader in developing examples that reach beyond my "comfort zone" of mathematics and physics. Since my current teaching is limited to Encounters I don't presently have a vast range of opportunities to apply what I've gained in the coming year, but I hope to do so on the future. My own scholarly and teaching interests are highly interdisciplinary, and I would greatly value the opportunity to share interdisciplinary investigation and learning with Whitman students.

Even within Encounters I will incorporate some of the taxonomy that we developed in the workshop for classifying types of science on the basis of the structure of the inferences made in the practice of the science. In teaching Darwin next year I will be better prepared to help students understand how his thought experiments and "storytelling" are a part of science. In teaching Bacon I will be better prepared to help students assimilate his concerns about the social forces at play in the practice of scientific inquiry. The workshop provided a number of examples that may prove useful in undermining the Kuhn-inspired skepticism about science that simmers throughout the humanities and even emerges in the Encounters classroom. These sorts of examples---examples of ways that the social conditions of scientific inquiry can promote objectivity rather than reaffirm entrenched interests---will help me to construct a more vivid counterpoint to the skeptical position that examination of the actual practice of science often engenders.

(c) I do not have concerns about the planning or design of the workshop.

Nick Bader (Geology)

The spring 2013 CDLTI "Scientific Inference" workshop was a successful attempt to discuss the practice of scientific inquiry and both its advantages and built-in shortcomings. Faculty from Biology, English, Geology, Mathematics, Philosophy, Physics, and Rhetoric all provided resources and presented readings for a variety of topics related to this common theme. I learned a great deal about the variety of ways in which science is done, the gulf between science and statistics, and the perception of scientific inquiry by non-scientists.

This workshop was not designed to generate new courses, but rather to discuss philosophical issues surrounding the process of scientific inquiry. The most important changes that I will implement as a result of this workshop will be in my work with juniors and seniors on their thesis projects: for instance I will focus more attention with my students on data curation and sharing, and keep careful records of nonsignificant relationships.

The design, organization, and implementation of this workshop were all excellent. Tim Parker did a fantastic job of coordinating the content of the workshop so that all of us were able to discuss the issues we thought were most important. I am very satisfied with the results.