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ABSTRACT

This paper explicates a notable difficulty faced by political science instructors who teach introductory courses in the scientific method to undergraduates or who, in substantive courses, wish to introduce their students to the scientific study of politics. The paper states that this difficulty arises because the majority of college students, like the majority of the lay public, accepts a number of myths about the political sciences. These myths cloud their understanding of social science and that social phenomena can be studied scientifically. The paper defines and discusses the character of five such myths, explaining the negative contrast with the social sciences that accompanies each one. It offers evidence from the physical sciences to explain how these myths incorrectly characterize scientific practice and results in those disciplines. It discusses teaching strategies by which political scientists can overcome these myths. The paper concludes that teachers must employ as much creativity in their teaching to dispel these myths as they bring to substantive research. Contains a 40-item bibliography. (Author/BT)

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Abstract

This paper explicates a notable difficulty faced by political science instructors who teach introductory courses in the scientific method to undergraduates or who, in substantive courses, wish to introduce their students to the scientific study of politics. This difficulty arises because the majority of college students, like the majority of the lay public, accepts a number of myths about the physical sciences. These myths cloud their understanding of *social* science and that social phenomena can be studied scientifically. Thus the myths are a significant barrier to educating our students about scientific practice in political science. I define and discuss the character of five such myths, explaining, as well, the negative contrast with the social sciences that accompanies each one. I offer evidence from the physical sciences themselves to explain how these myths incorrectly characterize scientific practice and results in those disciplines. And I discuss teaching strategies by which political scientists, indeed all social scientists, can overcome these myths.

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Myths About the Physical Sciences and Their Implications for the Teaching of Political Science

This paper describes misconceptions about the physical sciences that are widely held by college students today. These misconceptions, or myths as I prefer to label them, pose notable hurdles for students appreciating the social sciences as legitimate scientific enterprises. My purpose here is pedagogical, too. A general motivation for the paper is John Dewey's (1934) influential call for scientists and educators to instruct the mass public in what he termed "the scientific attitude" as an approach to reasoning *and* in the power, achievements, and challenges posed for society by modern science. More particularly, I respond to the persuasive, specific argument in prior scholarship that students must overcome various negative or unconstructive stereotypes to achieve scientific literacy.

Doubtless, scientific literacy is a complex concept itself, subject to various interpretations and hence methods of assessment (DeBoer 2000, Laugksch 2000). Yet a wealth of studies over the second half of the twentieth century, employing a variety of methods – some assessing "stocks" of scientific knowledge across a range of disciplines, some assessing general understandings of science and its methods, and some exploring the understanding of specific scientific concepts or bodies of knowledge – have consistently found significant shortfalls in what could be deemed reasonable scientific literacy among American high school and college students (for an extensive review of this literature, see Lederman 1992; for representative empirical studies of the scientific literacy of high school graduates or college students see Aikenhead 1987 and Bishop and Anderson 1990).

A common conclusion of the preceding research is that much misinformation about science takes the form of simplistic or flatly incorrect preconceptions or stereotypes. And one goal of education for scientific literacy is the eradication of such preconceptions. As Rutherford and Ahlgren (1990, 186) argue, "...learners must change the connections among the things they already know, or even discard long-held beliefs about the world.... If their intuition and misconceptions are ignored or dismissed out of hand, their original beliefs are likely to win out in the long run, even though they may give the test answers their teachers want."

Thus I elucidate the character of select misconceptions, or myths, among college students, and I explain both why they are erroneous and how they are problematic for the teaching of social science. I also suggest how they can be confronted and overcome in the classroom. My purpose, then, is to advance the teaching of social science *qua* science.

The particular misconceptions about science that I attribute to college students are not, of course, unique by some criteria. *General public* misunderstanding of science is widespread and has been frequently documented. For example, the National Science Foundation's report, *Science and Engineering Indicators 2002* (National Science Foundation 2002), provides extensive discussion of this problem. Data from an NSF survey of the mass public cited there indicate that less than a third of Americans could be considered as "understanding the scientific process" and that large percentages of the public misunderstand a range of basic scientific phenomena. Worse, large percentages of the public believe in one or more forms of pseudoscience such as astrology, extrasensory perception, ghosts, faith healing, communication with the dead, and the existence of alien visitors to the Earth from other parts of the solar system.

Some observers see more than mere ignorance in the preceding mass beliefs. Various

scientists and science writers have feared that misinformation about science, along with outright hostility to scientific research and the scientific community among some members of the public, could harm the role of science in society and opportunities for science to advance societal interests (e.g., Sagan 1996). Others fear that widespread scientific illiteracy will limit American achievements in scientific research by retarding the number of new scientists or by reducing public support for scientific research (National Science Foundation 2002). A third concern should be of particular interest for political scientists: whether a mass public that is not sufficiently knowledgeable about scientific affairs can play an effective role in the democratic process. As Prewitt (1983, 51) observes of this concern, "The lay public increasingly confronts a political agenda that has been fashioned by technical processes that only the experts can understand." An ill-informed public could, thus, communicate equally ill-informed messages about policy preferences through the mechanisms of the democratic process.

Social scientists may not have to confront in the classroom all the forms of skepticism and ignorance described by the National Science Foundation, even though some of our students surely harbor one or more of them. Nor are all these forms of scientific illiteracy of concern to the present paper. My teaching experience indicates that the greatest intellectual hurdle we face is of a more limited and particular character. Resistance to the belief that the social sciences are truly scientific arises especially from misconceptions about the physical sciences – our more mature scientific cousins. What students believe – incorrectly – about other sciences is one of our most important challenges. We must recognize, challenge, and attempt to correct these misconceptions to successfully instruct our students in the scientific study of social phenomena.

What I Mean by Myths about the Physical Sciences

I employ the term *myth* to designate a popular but erroneous belief that is usually based on simple-minded or only partial understanding of a subject. All the myths about the physical sciences I identify are rooted in some accurate knowledge. But each one includes enough misinformation to qualify as a "long-held belief about the world" in Ahlgren and Rutherford's language, that is sufficiently misleading as to hinder a reasoned understanding of science.

And how did I uncover these myths? Admittedly, not by the most rigorous of scientific procedures. Yet by a respectable one, nonetheless. I discovered these myths from direct and frequent observation of the subset of the mass public of interest here. For the past decade I have taught an undergraduate course in the science and methods of political science at least annually. For most of that decade I also taught a graduate-level version of much the same course to first-year, first-semester doctoral students. I routinely address the scientific character of political science as a fundamental topic in both of these courses. Thus I have articulated at length the basis on which we can make that claim for our discipline – with numerous comparisons to the physical sciences.

I also routinely probe the students in both of these classes about the prior introductions to the social sciences, if any, they have had, their perceptions of the legitimacy of the social sciences as sciences, and their objections to or reasons for skepticism about that designation. Prior exposure to this perspective in any notable degree is rare, even for the doctoral students. Yet, happily or not, the reasons students are skeptical about this idea are few, consistent, and widely shared. Thus what I have learned from this kind of observation of our students provides the basis for the present paper.

Myths About the Physical Sciences and How to Confront Them

My observation of and discussions with political science students and those majoring in various other disciplines reveal five especially common and critical myths that I discuss here.

Myth 1: *The subject matter of the physical sciences is always highly orderly, indeed, deterministic in its "behavior."* The invidious comparison, of course, in students' minds is that human behavior, some of the key subject matter for the social sciences, is highly unpatterned, disorderly, and unpredictable. And they believe that phenomena with the latter traits cannot be studied scientifically.

This myth invites various kinds of comments. One might first ponder whence it arises. And I suspect that the problem is largely caused by lazy or superficial thinking. Students likely assume that the orderly effects of gravitation in our immediate environment, as one example, or what they recall about the patterned character of many objects in our solar system can be generalized to all physical phenomena.

Other observers, however, make a compelling argument that the teaching of physical sciences is one cause of this misperception. Delamont and Atkinson (2001, 87) observe of laboratory sciences that "undergraduate laboratory experiments have been chosen and stage-managed ...so that they do, routinely, produce 'correct' results." Delamont and Aktinson make the same observation about instructional methods in field sciences. Further, the physicist A.B. Arons (1983, 100) argues that most science instruction and textbooks reify scientific knowledge, presenting it as "...inevitable, rocklike formations that have existed for all time...." Thus instructional practices and course content in many physical sciences characterize established knowledge in a way that re-enforces the stereotype of deterministic physical phenomena.

Whatever the source of this myth, we must confront and rebut it. I suggest two strategies for doing so in the classroom. First, one might discuss with students some of the many physical phenomena that are known to behave in probabilistic, highly complex, or seemingly chaotic ways. Examples abound. But consider the following ones:

- the expectation of probabilistic instead of deterministic physical phenomena in quantum physics and its attendant expectation of *uncertainty*, where "the uncertainty is inherent in the nature of things and ... the rigid connection between cause and effect is destroyed, because it is not certain that the cause will lead to the exact calculated effect" (Spielberg and Anderson 1995, 298).
- the unpredictable, trial-and-error character of the evolution of animal species, arising from randomly occurring trait variations and then "the natural selection of numerous, successive, slight, favorable variations" influenced to some degree, as well, by the external environment (Darwin 1998, 636-637).

Second, one can encourage students to consider more deeply the complexity of some physical phenomena about which they may be especially interested. As one example, the average college student should not require much of a reminder that the effects of alcohol on the human body are complex and not just deterministic. To be sure, we could hope they know that enough alcohol consumed in a sufficiently short period will lead "deterministically" to intoxication, first, and death, second. But they also likely know that the effects of lower levels of consumption on mental and motor skills vary by one's weight, coincident eating pattern, drinking experience, and even individual tolerance more generally. Thus at some levels of consumption the effects across individuals are complex, varying, and not deterministic.

Equally, cigarette smoking – another subject of interest to many college students for various reasons – has complex effects on the body. Even moderate smoking has certain deterministic effects on lung tissue, as one example. But the likelihood of contracting lung cancer even after a long period of smoking is either probabilistic in fact or simply understood as such by current medical science.

The central point to be made in response to this first myth is that natural phenomena – whether in the physical or social spheres – can evidence various different patterns of behavior. Such behavior might be deterministic or nearly so. It might instead only be probabilistically patterned, and with varying degrees of orderliness. It might even be chaotic. Some of these different patterns might be said to depend upon the "level of analysis" of one's observations. Individual, elementary physical particles may behave in seemingly random ways, while whole physical objects may behave deterministically in some respects in their natural environments. Equally, some forms of political behavior by individual people may appear disorderly from some observational perspectives. But from other perspectives individual political behavior – and especially that of aggregates of individuals – often conforms to notable patterns even if they are probabilistic ones. Thus the phenomena of interest to the physical and the social sciences are not notably different in these respects.

Myth 2: *The physical sciences are highly successful in explaining all the subject matter they study.* Students have a general perception of the physical sciences as being intellectually powerful and successful. They evidently judge those sciences as having notable stocks of knowledge, as they surely do. But there is little appreciation, unless one stimulates it, that there are contingencies in these stocks of knowledge or that there exists an intellectual frontier of

unresolved puzzles.

The sources of this second myth are likely the same as those for the first one. More important, however, is getting students to appreciate that it is not correct. Abundant examples exist, and from the commentary of physical scientists themselves. One excellent example comes from the study of elementary particles in physics and the so-called Standard Model – the prevailing theoretical paradigm to account for elementary particle behavior that has been widely hailed as one of the most successful scientific achievements of all time. Yet Nobel-laureate physicist Steven Weinberg (2001, 199-200) has observed:

> "Even though the Standard Model provides the paradigm for the present normal-science period in fundamental physics, it has several ad hoc features, including at least eighteen numerical constants, such as the mass and charge of the electron, that have to be arbitrarily adjusted to make the theory fit experiments. Also, the Standard Model does not incorporate gravitation."

One could conclude on the basis of the preceding remarks that the Standard Model has a very long distance to go to account well for the real-world phenomena it is meant to explain.

Beyond using such particular examples, I encourage students to consider distinctions about the character of knowledge in scientific disciplines. A variety of treatments in the history, philosophy, and sociology of science agree that every scientific discipline has a body of knowledge that is generally accepted as useful description of or theory about its subject matter. Yet every discipline also has a good deal of other knowledge, often that in the most recently completed or published research, that is controversial or whose utility or satisfactoriness is not yet clear. For conceptual distinctions related to these different kinds of knowledge consider

Kuhn's (1996) delineation of paradigmatic knowledge and that which challenges the dominant paradigm and Zuckerman and Merton's (1973) characterizations of codified, theoretical knowledge and more disparate, particularlistic knowledge that is not codified into accepted general theory. Cole (1983) makes the especially useful, related distinction between the *core* of knowledge and that which is at the *frontier* of the discipline. Further, Cole (1983) has demonstrated with a variety of clever empirical analyses that the research practices at the frontiers of different sciences are essentially identical. And his research specifically demonstrates that the work of social scientists at the frontiers of their disciplines is comparable to that of the same work by physical scientists.

It is widely agreed, then, that every discipline has a frontier of knowledge, often addressing unsolved puzzles and where a good deal of research is of disputed or unclear utility. Older, more mature disciplines may have larger cores of knowledge than do younger ones, but all of them face a range of unresolved puzzles and research challenges. If our students can appreciate these distinctions, they have a more sophisticated basis for comparisons of the physical and social sciences.

One could also develop a host of specific examples (and perhaps more accessible ones than the example above about the Standard Model in physics) where the physical sciences face notable problems at the frontiers of their disciplines. Davies (1995, 279-283) and Hagen (1997) present extended catalogues of unanswered, fundamental questions across a range of physical sciences – written for a lay audience. Alternatively, one can generate a host of examples from those current scientific affairs that the mass media deem worthy of extensive coverage. Consider as examples:

- the puzzling appearance of health threats like AIDS, Creutzfeldt-Jakob disease, and SARS that have somehow been transmitted from animal species to humans.
- the debate in astronomy over the existence and character of *dark matter*, thought to account for most of the mass in the universe even though its existence is only hypothesized and it has not been observed (Hazen 1997, 11-27).
- the "Big Bang" theory that is the leading candidate to account for the creation of the Earth and the universe, but for which there remain important, observable phenomena that the theory cannot explain (Zeilik 2002, 466-482).

Myth 3: *The physical sciences have always been highly successful in explaining the subject matter they study.* This myth is a subtle corollary to the one above. If we lament that students know no history of politics, they are equally ignorant of the history of science – and with equally unfortunate consequences. Here, however, they have likely once heard examples from the history of science that contradict their misperception. But such examples must be evoked and re-interpreted to overcome the underlying myth.

One valuable approach here is to help students distinguish and appreciate the differences between young and mature scientific disciplines. I characterize young sciences as typically suffering from limited agreement on the most important problems or puzzles; a modest, shared observational or theoretical knowledge base; little in the way of shared procedures or tools for knowledge collection – and with frequent resort to what would in a mature science be considered quite rudimentary procedures and tools; and little or no public respect for their, admittedly limited, achievements. Indeed, on the latter point young sciences often have to compete on especially weak terms with "other forms of knowledge" (Kerlinger 1973, 2-6) like commonsense,

religion, and other sources of authority. I often describe early astronomy in these ways, adding a range of particular details to the preceding generalities. And this characterization of young astronomy maps well in general terms to political science today. One could develop similar characterizations of early scientific practice in chemistry, physics, medicine, or likely any discipline.

Another educational strategy is to remind students of how recently many physical science disciplines were characterized by what we now know is quite erroneous or even destructive knowledge. Good examples are numerous. Perhaps, a useful contemporary one concerns diet and health. College students today are likely to recognize, for example, that modern medical and dietary science have exhibited notable controversy and reversals of conventional wisdom about the importance of different dietary components – protein, fats, carbohydrates, and nutritional supplements – for health. Even recognizing and setting aside the numerous wacky and commercially entrepreneurial nutrition advice-givers, the strictly scientific community has at times advocated a range of different ideas, some of which have now been discarded or substantially qualified.

A compelling historical example relates to the work of Louis Pasteur, who began his revolutionary research in chemistry on disease, fermentation, and related processes in plants and animals in the 1840s. At that not-so-distant time, lay public and much scientific knowledge of these matters was quite primitive. As Perutz (1995, 54) observes, "The causes of infectious diseases were unknown. Malaria was believed to arise from 'miasmas' emanating from swampy ground; outbreaks of plague were attributed to unfavorable constellations, to comets, to the wrath of God, or even to the poisoning of wells by Jews." Indeed, Pasteur's ideas faced considerable

opposition from his fellow scientists who were wedded to many primitive and erroneous beliefs about such phenomena (Debre 1998, 257-314).

A final, remarkable example of erroneous knowledge of sorts relates to the work of Isaac Newton. Newton is venerated, of course, for his pioneering work in physics and, in particular, for his theoretically masterful *Philosophiae Naturalis Principia Mathematica* that charted the course of much of the physical sciences even to the present day. But it is sobering to know that Newton spent far more of his scientific lifetime in the study of alchemy than of physics (Westfall, 1980, 281-334 and 469-550).

Myth 4: *The concepts in the physical sciences refer to concrete, easy-to-understand things rather than the highly abstract and often difficult-to-define things that political scientists study (such as democratization, partisanship, ideological disposition, and the like).* Students with little formal training in science, surely most of the ones we encounter in introductory courses then, rarely are able to think systematically about the *concept* of *scientific concepts*. And they are especially unlikely to recognize both the abstract and the operational components of all such concepts. But, again, they have stereotypes about concepts from the physical sciences. And these stereotypes suggest that the latter concepts, and thus all attributes of physical matter, are fixed and immutable things. One could even suggest that students believe that the attributes of physical phenomena we endow with meaning conceptually are concrete aspects of physical things that exist regardless of whether and how we perceive them.

In contrast, students new to political science are uneasy about many of our central concepts. Democracy and autocracy as attributes of political systems and ideology, partisanship, and efficacy as attributes of individuals seem too abstract and contestable to form the basis for

scientific study.

But what a superficial misconception this is about the character of concepts in science generally. Likely every concept of importance in any science was once quite abstract and suffered contested meaning within the discipline. Further, as Arons (1983, 92) explicitly argues, scientific literacy requires the recognition that all "...scientific concepts (e.g., velocity, acceleration, force, energy, electrical charge, gravitational and inertial mass) are invented or created by acts of human intelligence and imagination and are not tangible objects accidentally discovered, like a fossil, a new plant, or a particular mineral." Arons goes on to explain how scientific concepts *routinely* evolve in meaning and precision.

Example concepts from the physical sciences for countering this myth are abundant, and they can support rich anecdotes that underscore both the intellectual disagreement that occurs in all disciplines and how intellectual progress often revolves around the resolution of disagreement about the meaning of core concepts. Arons (1983, 101) discusses a concept from physics in this way, illustrating in particular how the meaning of a concept can evolve – and in a fashion that can be readily generalized to political science concepts:

> "...the concept of 'force' is legitimately introduced by connection with the primitive, intuitive, muscular sense of push or pull, but in the law of inertia, we redefine it to apply to any effect that imparts acceleration to a material object (for example, the action of an electrically charged rod on bits of paper). We endow completely inanimate objects with the capacity to exert forces on other objects (the charged rod exerting a force on the bits of paper, the table exerting an upward force on the book that rests upon it, the earth exerting a downward force on us – our weight – and an upward force at our feet).

Following Newton, we then extend the concept even further and create the idea that when the table exerts a downward force on the book, the book simultaneously exerts a downward force on the table. We have come a long ways indeed from the original use of the word 'force' for an animate, muscular push or pull on another object."

The concept *force* shares close parallels with the development of many concepts in political science. Consider the concept *democracy* as an attribute of a political system. Recall the limited, intuitive character of early, modern-science definitions of that concept like that of Lipset (1959, 71) wherein democracy "is defined as a political system which supplies regular constitutional opportunities for changing the governing officials. It is a social mechanism for the resolution of the problem of societal decision-making among conflicting interest groups which permits the largest possible part of the population to influence these decisions through their ability to choose among contenders for political office." Recall, too, how Lipset's operational version of the concept is based on what must be called casual observation of political systems.

Consider next, using Aron's terminology, how subsequent scholarship has "endowed" the concept of democracy with richer, more precise, and more complex meaning – as can be seen in various definitions based on the conceptual work of Dahl (1971) like that of Bollen (1980) or in the POLITY definition (Jaggers and Gurr 1995) based on the "patterns of authority" conceptualization from Eckstein and Gurr (1975). The operational definitions for the contemporary conceptions of democracy are also more complex (indeed, they are commonly multi-dimensional), explicit, and discriminating than Lipset's – another common product of conceptual elaboration.

The concept of democratization or degree of democracy has been extended in other ways,

too, just as has the concept of force. The range of application of the concept has been extended far beyond its original application to whole, national political systems. Democratization has been systematically applied to or assessed in such other institutional processes as subnational political systems (e.g., Hill, 1994), election systems for particular public offices (e.g., Ragsdale 1989), and the comparison of alternative national election systems in polyarchic nations (Powell 2000).

One could develop other expositions of political science concepts that have evolved in the same way. But my principal theme, of course, concerns the complexity of physical science concepts. And other notable examples from the physical sciences include:

- Lay people likely assume such commonplace physical phenomena like *light* have long been well understood by physical scientists. Yet the character of light and its composition were long contested – was light a wave or a particle? How was it transmitted and through what medium? – until well into the twentieth century (Park 1997, 310-338).
- Lay people likely also assume that astronomers long ago settled the definition of such common solar objects as *planets*, *stars*, *moons*, and the like. Yet the recent debate about whether Pluto is a planet reveals the limited precision of some of these concepts (Cowen 2001).
- The concept of the *mass* of physical objects would also like seem fundamental and concrete to the lay public. And it has been a fundamental concept for theory in physics at least since Newton. But Weinberg (2001, 193-194) observes that Einstein's theory of general relativity created uncertainty for a time among physicists about how to understand mass. Indeed, one of Weinberg's (2001, 194)

summary observations about this debate bears recitation: "Meanings [of concepts] can change, but generally they do so in the direction of an increased richness and precision of definition."

- And how many of our students, much less many students majoring in the physical sciences are intellectually prepared to confront the meaning of *time* as it has been portrayed in modern physics where "Einstein's theory of relativity introduced into physics a notion of time that is intrinsically flexible.... No longer could one talk of *the* time – only my time and your time, depending on how we are moving. To use the catch phrase: *time is relative*" (Davies 1995, 32-33). More complex still is the single, unified concept from relativity theory of *spacetime* (Davies 1995, 73).

For debunking the myth of concrete physical concepts it is also useful to employ some of the now-discarded and discredited concepts that were once central to many sciences. Consider here:

- The concept of *philogiston* – that was thought to a substance in all combustible matter – and that was central to most theory in chemistry until it was debunked by Lavoisier in the late 1700s (Conant 1950).
- The concept and alleged substance of *ether* that was presumed by physicists to fill all of space until it was proven specious by experimental work by Albert Michelson and Edward Morley in 1887 and entirely discarded with the acceptance of Einstein's theory of relativity – hence only in the twentieth century.
- Medical science no has a place in its explanations of physical phenomena for the four *humors* believed to arise from separate bodily fluids. Recall, too, that

medical science based on humors and extended to the practice of bleeding ill patients to cure them has a connection of sorts to American politics. Ill-advised bleeding of our first president, George Washington, has been implicated in his death – as treatment for a throat malady that might have been diphtheria or a streptococcal infection! (for an especially detailed account of Washington's medical treatment and subsequent death see Flexner 1984, 399-406).

Myth 5: *Physical scientists are entirely objective about their research and never affected by subjective values or preferences, whereas social scientists cannot escape subjective biases because their subject matter is humankind.* Many times I have heard students make a comment like, "No chemist would suffer affection for oxygen that would influence his or her work." Weinberg (2001, 200) echoes this sentiment when he observes, "We don't study elementary particles because they are intrinsically interesting, like people. They are not – if you have seen one electron, you've seen them all." But Weinberg, unlike the typical student critic, recognizes that passion in science is not so much about the phenomena themselves as about what explains their behavior. And scientists in all disciplines can be passionate about their theories and explanations, and their *individual* work can suffer – or benefit – from that passion.

Indeed, it is widely observed that science – in all disciplines – is an entirely human enterprise, subject to the vagaries of creativity, passion, discipline and even bias, chance, and perfidy. Similarly, Cole (1983, 131) has argued that research at the frontier of every science is less rational than is widely believed. Zuckerman (1991, 151-181) explicates this circumstance especially well for students in introductory political science courses. Related to my central thesis, further, Arons (1983) faults the teaching of physical science once more for creating

misconceptions about these facts. He argues that typical courses and textbooks isolate scientific knowledge from the human, fallible process by which this knowledge is created. Such treatments rarely encourage the student to appreciate the provisional character of that knowledge either.

The history of science is rich with examples from every discipline of how knowledge is shaped by human values. Consider three examples where, respectively, knowledge has been influenced by sheer passion for one explanation of phenomena over others, by monetary gain, and by the gender of the scientist:

- Referring to passion, Weinberg (2001, 201) describes the vehement disagreement among schools of physicists studying the origins of the solar system and observes: "I remember when most astronomers and astrophysicists were partisans of some preferred cosmology, and considered anyone else's cosmology mere dogma."
- on monetary gain, consider some of the scientific research on the effects of the weight-loss drug ephedra, that has been linked to over 100 deaths, including that of Baltimore Orioles baseball player Steven Bechler. Recent court findings indicate that some scientists doing clinical trials of the drug for its manufacturers effectively lied about or "fudged" their results to make the drug appear more effective or less likely to have adverse side effects – because they were being paid by the manufacturers to carry out the clinical trials (Fessenden 2003).
- Even the gender of a physical scientist can shape research and findings, as Rutherford and Ahlgren (1990, 8) have noted: "...for many years the study of primates – by male scientists – focused on the competitive social behavior of males. Not until female scientists entered the field was the importance of female

primates' community-building behavior recognized."

Once they appreciate the general argument here about "irrational" influences on the beliefs and practice of individual scientists, students should be taught how the collective practice of science imposes safeguards, fallible though they may be, on the effects of such influences. The expectations of full disclosure of the procedures and evidence for one's findings, peer review for grant funds and publication opportunities, and healthy climates of skepticism and criticism help weed out or suppress faulty claims to knowledge. Indeed, one could argue that science benefits from a tension between the creative, passionate individual search for knowledge and the conservative, collective appraisal of the products of individual effort. And the latter process of collective appraisal seems quite healthy in political science – through vigorous debate, skepticism, and high standards of peer review for grants and publication.

Conclusion

Almost seventy years ago John Dewey (1934) argued that the scientific community has as great an obligation to educate the mass public in an understanding of science as it does in advancing its own specialized professions and bodies of knowledge. Clearly, subsequent generations of scientists and educators have struggled to fulfill that obligation. Lamentations about the limited state of scientific literacy in the mass public have been commonplace over the years since Dewey's call, and there appears no reason to believe they will diminish in frequency – or that there is cause that they should. Because the discipline of political science evolved in the twentieth century into a predominately scientific one, we share the obligation Dewey articulated. But our goal, in my view, is not to join in the lamentations but to work at this task with the same

passion we bring to our search for knowledge of political phenomena.

We have particular reasons, as well, to pursue this goal. As I have argued elsewhere (Hill 2002) and alluded to above, ours is a young scientific discipline that suffers the ignominies of all such disciplines. Among those is modest public understanding or appreciation. Indeed, skepticism about our scientific legitimacy is surely more common than is acceptance thereof. Thus we have particularly compelling reasons to advance public literacy about our own discipline. And to achieve mass appreciation of our work, we likely must convert one "mind" at a time, or perhaps one classroom at a time. We have the simultaneous goal, of course, of converting those minds and classrooms into political scientists – at least at some level of intellectual appreciation and, perhaps, of actual practice for the time they are our students.

Prewitt's (1983) concern about how scientific advances may compromise the role of the mass public in the democratic process suggests a second reason we should seek to promote scientific literacy. Such literacy may be a fundamental part of civic education for citizens of democracies today. Civic education often focuses on the machinery of government. But to the extent that it addresses the problem and issue agendas of government, a basic knowledge of science, its uses, and its limitations seems essential for democratic citizens. Thus whatever we can do to advance scientific literacy may be central to the effective workings of democratic government.

There are doubtless many challenges for meeting the educational objectives outlined in the preceding paragraphs. A critical one as I have argued here, however, arises from the misconceptions students have about the more mature physical sciences – and the derogatory beliefs about the social sciences that result from those misconceptions. As Alhgren and

Rutherford (1990, 186) argue specifically about such misconceptions, we must confront them directly. In my view we must employ as much creativity to dispel them in our teaching as we bring to our substantive research. Thus I have outlined in this paper the most critical of these misleading ideas along with a range of teaching strategies that might overcome them.

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