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Teaching the Scientific Method in the Social Sciences

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Abstract

Many undergraduates can tell you what the scientific method means but just a little probing reveals a rather shallow understanding as well as a number of misconceptions about the method. The purpose of this paper is to indicate why such misconceptions occur and to point out some implications and suggestions for teaching the scientific method in the social sciences. This paper describes how students come to internalize key words and views about science without grasping some important concepts such as inference. I suggest that misunderstandings and misconceptions about science are the result of how it is transmitted to students. Misconceptions are easily perpetuated through the twin processes of diffusion and socialization. The social sciences can provide a corrective to this situation by first recognizing how textbooks and teaching approaches may contribute to the problem and, secondly, by developing innovative teaching strategies. This essay is based on observations made while teaching introductory anthropology and sociology courses to students of all majors.

Keywords: Scientific Method, Science, Social Science, Misconceptions about science.

Teaching the scientific method is a staple of standard introductory social science courses such as sociology, anthropology, psychology, and political science. For instance, sociology textbooks typically devote a chapter to research procedures designed to show students how scientific research is achieved. While such coverage in introductory textbooks is meant to provide the basics, most students come into social sciences classes already armed with some notion about how scientific research is conducted. From as early as grade or middle school, and certainly since high school, students begin accumulating the scientific wisdom of their science teachers. Once in college, students again enroll in courses that refresh their memories about the scientific method, in case they have forgotten what they learned in high school, and hopefully build on this knowledge. Students internalize the words and phrases they have associated with science throughout their school years. Underlying this apparent knowledge, however, is a lack of understanding of what it means "to do science".

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Observed Problems in the Classroom

The following are a few examples of the superficial understanding of science and some misconceptions students in my classes have demonstrated. Students correctly tell me that science is "empirical" but when asked to explain what this means they stumble around trying to explain this in their own words or provide good examples. Many students are quick to show their knowledge of science and the scientific method (henceforth, TSM). When asked how TSM works, a typical response might be, "Well, you have a hypothesis and then you test it." And when asked to define 'hypothesis', the typical response is: "It's an educated guess". Asking students to go beyond this ready answer becomes a painful exercise for many. To the question of how data may be collected, a favorite reply is "you do an experiment". Students are also limited in their thinking about such related concepts as assumptions and inferences. I was speaking to a pre-med biology major who recently took my sociology course. The issue of assumptions came up and she commented that making assumptions is dangerous and that she will not be able to make assumptions when she becomes a doctor because that could jeopardize her patients. She was trying to make the further point that we in sociology can make assumptions but in "the sciences" making assumptions is less acceptable. I was struck by the conversation with this student because it revealed some misconceptions about the scientific enterprise that I believe many students possess and it also hinted at a potential source of such misconceptions.

In this essay I suggest an explanation and point to some implications for teaching TSM. Based on my observations and probing of student thinking, I believe an explanation for such misconceptions can be sought in the concept of culture and I suggest that courses in the social sciences have the potential for providing a corrective to these misconceptions. While I draw examples mostly from my own classes in anthropology and sociology, my experiences in these two disciplines are clearly applicable to the other social sciences because of shared concerns and concepts. For instance, the concept of culture is an essential concept in anthropology and sociology but is also relevant to all the social sciences. Most social scientists conceive of culture as something that may at times be difficult to define concretely but which nevertheless is composed of material and nonmaterial items, the latter typically comprised of beliefs, values, and norms (Ferrante, 2008; Macionis, 2009).[2] In this essay I point out some of the elements of the "culture of science" and the "culture of education" that contribute to student misconceptions of TSM.

The scientific community and the educational institution can rightly be considered 'subcultures' each with its own set of material and nonmaterial components. Scientists, including social scientists, share a set of beliefs, values, and norms and employ various material items that form the toolkits of both the natural and social sciences. This is also true of educators. Just as cultural traditions in society are rarely questioned, so too, accepted ways of doing things in science and in education become normative and routine.

[2] This sort of view of culture is fairly limited but common in sociology textbooks and it should be noted that anthropologists have developed this concept more fully and deeply since the concept was first developed in the discipline beginning with Sir Edward Burnet Tylor.

The culture of science and the culture of education inadvertently and ironically contribute to student misconceptions about TSM. The physical and natural sciences (biology, chemistry, physics, etc.) have contributed to the culture of science historically since it has been in these disciplines that the tenets and procedures of scientific research have been most rigorously established and then emulated by others. Textbooks as part of the culture of education have also contributed to some of the limited notions and misconceptions students have come to embrace. For instance, Hood (2006) describes how some of the erroneous views students have about qualitative research are, in part, based on limitations of textbooks themselves. As she points out, students tend to regard textbooks as "gospel truth", thus requiring teachers to "go beyond both textbook myths and mainstream folklore" in order to overcome some of these misconceptions (p. 207).

Some of the weaknesses of student thinking about TSM have been revealed time and again in a simple exercise I employ to engage students in deeper discussions about TSM. This exercise involves showing a cube with the numbers one through six on its sides with the even numbers underlined (Keyes, 2002; National Academy of Science, 1998). The exercise has obvious limitations but it is meant to show in a simplified way aspects of TSM. Students make initial observation about what they see; they are shown all sides except the bottom of the cube such that they see all the numbers except the one on the bottom. I ask them to formulate a question, and then to propose a possible answer (a hypothetical statement) based on their observations. Then they suggest potential bits of evidence that might support their hypothetical statement. In the end, I ask them if they are convinced of the answer (whether the hypothesis has been 'proven' to their satisfaction). I point out that the evidence they have provided has convinced me of the correctness of the 'hypothesis'. However, most students remain absolutely skeptical with only 5% - 8% accepting the conclusion. To be skeptical is certainly an essential part of the culture of science. However, when asked to explain the reasons for their skepticism most students provide a simplistic answer that reveals a rather limited view of science. In the class activity described above, the bottom of the cube is never shown; therefore, most students are very skeptical about accepting the conclusion I have reached. Asked about their skepticism, they first point out that since they have not actually seen the bottom of the cube, the conclusion is not 'proven'. They suggest that anything could be at the bottom and that perhaps I have tricked them by not even putting a number on the bottom of the cube. Many of these students were majoring in the sciences so I became curious about how their perception of TSM might be informed by the science courses they take. To get an idea I had students collect definitions from their science textbooks. In one class there were twenty definitions from courses such as biology, chemistry, and geology. The natural sciences provide a view of TSM that is certainly accurate and suitable but which inadvertently has led to certain misconceptions.

Textbook Definitions of the Scientific Method

Definitions of the scientific method can be found in textbooks in both the social and natural sciences and, while some variation exists, all have certain common features. Students collected a number of definitions of TSM from textbooks in the natural ("hard") sciences and then were asked to compare these to the one provided in their sociology textbook.

Some definitions list the steps or process involved while others provide a general overview of what is meant by TSM. Take for instance, the following examples.

From a textbook in geology text: “Scientific method – a logical, orderly approach that involves gathering data, formulating and testing hypotheses, and proposing theories” (Wicander & Monroe, 2006). From a chemistry textbook: “Scientific method – Scientific questions must be asked, and experiments must be carried out to find their answers” (McMurry & Fay, 2008). From a biology text: “The classic vision of the scientific method is that observations lead to hypotheses that in turn make experimentally testable predictions” (Raven, Losos, Mason, Singer, & Johnson, 2008). From a psychology textbook: “The scientific method refers to a set of assumptions, attitudes, and procedures that guide researchers in creating questions to investigate, in generating evidence, and drawing conclusions” (Hockenbury & Hockenbury, 2000). From a sociology textbook: “The scientific method is an approach to data collection that relies on two assumptions: (1) Knowledge about the world is acquired through observation, and (2) the truth of the knowledge is confirmed by verification--that is, by others making the same observations” (Ferrante, 2008).

It is clear that TSM is perceived similarly in both the natural and social sciences, although one notices slight differences in emphasis as suggested by the vocabulary used in these definitions. The similarity is certainly expected since the social sciences attempt to emulate the systematic approach developed in the physical and natural sciences. Common terminology represents the common jargon that is part of the lexicon of science. Students in the social sciences understand that culture has certain basic components such as language, beliefs, values, and norms. Hence, the lexicon of TSM can be equated to the linguistic component of the culture of science. The lexicon of TSM has been adopted not only by the social sciences but also by general education and the public.

The most salient terms, what linguistic anthropologists would call the “basic vocabulary”, of TSM include “systematic”, “procedure”, “empirical”, “method”, and “objective”. More specific but equally salient terms are “discovery”, “fact”, “hypothesis”, and “experiment”. The first set of words point to a more general definition of TSM while the second set suggest some of the more specific elements of TSM. Both the natural sciences and the social sciences employ the same lexicon with very little variation, an understandable situation if you consider that both the natural and social sciences share the ‘culture of science’. A common culture of science would include not only a lexicon (language) but also norms (rules of behavior) and sets of beliefs. The norms of the culture of science revolve around how scientific work is to be conducted, the procedures used, and the steps taken in doing research. This view is explicit when Bernard states that “The norms of science are clear” (1995, p. 3) and proceeds to state that these norms include objectivity, a systematic method, and reliability. Quoting Lastrucci (1963), Bernard further points out: “Each scientific discipline has developed a set of techniques for gathering and handling data, but there is, in general, a single scientific method. The method is based on three assumptions: (a) that reality is ‘out there’ to be discovered; (b) that direct observation is the way to discover it; and (c) that material explanations for observable phenomena are always sufficient, and that metaphysical explanations are never needed” (Bernard 1995, pg.

3-4). This description summarizes rather well the major elements of TSM that are largely shared by both natural and social scientists.

How Misconceptions Develop

Most social scientists across disciplines such as psychology, sociology, anthropology, and political science would agree that the culture of science as described above is shared by natural and social scientists alike. Possessing a common culture does not prevent, however, the development of certain misconceptions. I focus on two factors (processes) that have contributed to the misconceptions about the TSM among social science students: (1) The social sciences (sociology, psychology, anthropology, political science, etc) have adopted much of the culture of science without much modification and (2) much of this adoption comes about through socialization.

The first factor deals with the diffusion or the spread of cultural elements from the natural to the social sciences. Chief among these is the spread and adoption of the language of science. This is expected since historically the social sciences have tried to emulate the natural sciences. In my classes it is evident that students have internalized the lexicon of science without giving it much thought. This is quite understandable. After all, learning the culture of science is analogous to learning one's culture through the process of socialization. The culture of science is shared because members of the scientific community "have undergone similar educations and professional initiations; in the process they have absorbed the same technical literature and drawn many of the same lessons from it" (Kuhn, 1970, p. 177). Whether socialization is achieved formally or informally, most individuals come to internalize cultural patterns without much analytical reflection. At some point students seem to take TSM for granted, much as we take language for granted, using it without really reflecting on it. This is reinforced by the fact that the scientific lexicon consists of a number of terms that are also part of our everyday English-language. Hence, the lexicon of TSM sounds familiar to students who have heard these terms used over and over again and is indeed part of everyday vocabulary. Students come to believe that they know what they are talking about by merely employing the correct terminology. For example, the words "fact" and "proof" are used in science and are also part of everyday American lexicon. The common everyday use of such terms gives student a sense of comfort and familiarity since these terms are also part of the everyday language. For most students, a fact is a fact, and proof is proof; if something is a fact, it needs no further exploration and is simply accepted as an absolute, especially if these 'facts' come out of the halls of the hard sciences. Terms such 'hypothesis' and 'theory' are perhaps more specific to the culture of science, but they have also become part of the lexicon of every English speaker and hence, carry everyday connotations that may actually differ from the way scientists use these terms. Hypothesis and theory are often perceived by students (and the general public) as opposed to 'fact' and 'proof' such that if something is a 'theory' it cannot be a fact. This is exemplified by the common misconception about the word theory. Take for instance, the current view by many Americans that evolution is "just a theory". Most students and Americans in general do not consider that a theory (such as the theory of evolution) is both a theory and a fact as Stephen Jay

Gould eloquently reminds us (1981). The diffusion of TSM method beginning with its lexicon is thus often superficially understood.

By simply borrowing the lexicon of science and failing to see TSM as a social construct, students often develop misconceptions and a narrow view of how science works. They also fail to see that as a cultural construct, TSM is an ideal that at times must be adjusted to differing contexts. As Oren (2006) and Gordon (2002) point out, TSM has certain limitations when applied to highly complex phenomena as social behavior. Even Bauer (1992, p. 147), who is a chemist and hence a 'hard scientist', points out that "the scientific method is an ideal". To most undergraduate students, however, TSM appears concrete and an inviolable aspect of doing scientific work. The first inclination of students is to suggest that experimentation is how one must gather data in order to confirm or disprove a hypothesis. But when confronted with a social research question involving humans, students stumble around trying to figure out how or what sort of an experiment one could devise. Obviously, some social experiments are possible and are indeed carried out, but it seems that students come to the social sciences with a fairly narrow conception of 'experiment' that is more appropriate to laboratory settings.

Limitations and Misconceptions

Focusing on the culture of science and education and the processes of diffusion and socialization helps to explain why many students have a limited view of science. The problems I have observed are clearly intertwined such that addressing one misconception necessarily brings up other related ones. Some concepts are interpreted or perceived in limited or literal terms and other important scientific elements are more likely to be simply ignored. Common tendencies I have observed include the following.

- Literal view of "Observation" – While observation is the cornerstone of TSM, students tend to be literalists. Textbooks teach them the importance of "direct observation" and in the mind of many students "direct observation" means exactly that! This is ironic, because while they hold onto the belief in the importance of direct observation, they are often all too willing to accept non-empirical conclusions, so long as these come from textbooks, experts, or other authorities.
- Absolutist view of "Proof" – Students often see scientific findings as definitive, concrete, and absolute as in a mathematical truth. Their mathematical-like definition of proof results in a misplaced skepticism; something cannot be proven if it has not been directly observed. Nevertheless, they are often willing to accept repeated citations as proof as long as such repetition comes from perceived "experts" or authorities such as textbooks.
- Narrow meaning of "Fact" – Like the concept of 'proof', there is a tendency to see fact as absolute truth and as an opposition to theories and hypotheses. In a similar way, they often see the findings that come from the hard sciences as simply factual, real and concrete. Pointing out how the 'facts' of science have changed over the years (such as the 'fact' that Pluto was but now is not a planet) helps students begin to see the changing nature of 'facts'.

- Narrow view of “experimentation” – The physical and natural sciences tend to emphasize experimentation as a key way to collect data. Indeed, some of the definitions of TSM provided above clearly point to this emphasis. The common image of experimentation is that of laboratory experiments and medical clinical trials. The importance of experimentation is reinforced in standard textbooks in both natural and social sciences as the textbook definitions cited above exemplify. Moore & Vodopich (2008) are explicit in showing the importance of experimentation in data collection. They state: “Do experiments to gather data”. Such guidance in the natural sciences becomes part of how students perceive TSM as a whole, leaving them puzzled about how to be scientific in fields like sociology or political science since experimentation does not become readily apparent or feasible in the social sciences.
- Neglecting the role of “Inference” – Few students recognize the significance of inference in science even though inference is fundamental to all science. At the heart of inductive reasoning is the ability to infer from the available evidence and yet few students even consider its significance in ‘normal science’ to use Kuhn’s term (1970). This neglect is due, in part, to previously mentioned misconceptions about ‘observation’, on the one hand, and ‘facts’ on the other. To many students, inference does not seem compatible with their rather literalist view of empiricism and facts. If something is inferred it must mean that one’s conclusion was not really observed; hence, students see an inference as characterized by uncertainty and, therefore, unscientific. And yet, the prevalence and importance of inference in science is demonstrated by scholars who have directly addressed the concept. McMullin (1992) in his Aquinas lecture, *The Inference that Makes Science*, demonstrates in a philosophical and historical perspective how inference has been an element of science beginning with Aristotle’s view that ‘demonstration’ is what makes knowledge scientific.
- Neglecting the role of “Assumptions” –Another neglected or misunderstood factor is the role of assumptions in the course of science. Many students believe that assumptions are to be avoided because assumptions suggest that something is not solidly factual, such as was illustrated by the anecdote told above about the biology student who mistrusts assumptions. In the view of many students, the term assumption has a negative connotation. Like the concept of inference, students seem to believe that assumptions are contrary to science.

Implications & Strategies for Teaching

The social sciences today strive to be scientific in their research. For instance, sociology from the time of Auguste Comte and Emile Durkheim, has explicitly cultivated the belief that society and social behavior can and should be studied from a positivist approach, a long-lasting legacy seen in contemporary disciplines such sociology, anthropology, and psychology, all of which see themselves as scientific. Of course, there have been many discussions about whether or not, or to what extent, sociology and other social sciences can rightly claim to be a science (e.g., Gordon 2002; Oren 2006; Bauer 1992). The distinction between the “hard” and “soft” sciences is often brought up to show that the social sciences are different from the natural sciences in their methodology and subject matter.

These sorts of debates notwithstanding, the current consensus in sociology is that sociology is indeed scientific in its overall goals and methodology. As Bauer (1992, p. 137) points out, "social scientists are much more consciously scrupulous to follow the scientific method than are scientists themselves…" In so doing the social sciences have tended to reinforce a rather strict view of TSM that perpetuates some of the misconceptions noted above.

Social scientists have long been aware that some of the methods employed successfully in the physical sciences cannot be directly applied in the social sciences. For instance, many years ago Chapin (1917) with regard to sociology observed that the "experimental method has brought notable achievements in physical science" but in sociology strict control of conditions and isolating factors that such a methodology requires is not so easily achieved. He concluded that a statistical method in sociology would be analogous to the experimental method in physical science. Similarly, but ninety-two years after Chapin's observations, Pigliucci states that the "so-called soft sciences are concerned largely with complex issues that require sophisticated, but often less clear cut, approaches; these approaches may be less satisfactory (but more realistic) than strong inference, in that they yield probabilistic (as opposed to qualitative) answers" (2009, p.3).[3] In a similar vein, Lenkeit (2009) enumerates some of the difficulties of attempting to apply the scientific method as developed in the natural sciences to the social sciences. Among the difficulties are the complexity of the subject matter and the difficulty of isolating variables. These difficulties, however, should be welcomed for they provide the opportunity to guide students into a deeper understanding of TSM. Misconceptions students have can be corrected while developing a deeper appreciation of the complexities of the subject matter with which the social sciences deal.

Since textbooks are used routinely in higher education today, it is also important to consider the role that textbooks play in education. This implicates both scientists and social scientists in perpetuating the limited view of science that students appear to hold. Another implication is that social scientists can play a significant role in providing balance and a broader view of science and TSM than they have done in the past.

Instructors in the social sciences can work to ameliorate this situation by implementing teaching strategies that encourage students to think more critically about TSM. In so doing we help students become stronger thinkers. Developing such teaching strategies tailored to specific disciplines requires some creativity on the part of instructors. Nevertheless I suggest a few general approaches that I and others have used that are applicable to all disciplines and with some modifications can be customized.

- TSM Cube. As described earlier in this paper, I use what I call "TSM Cube" to engage students in a discussion of the basic steps of scientific research. It is a simple activity that only requires a small box onto which you can write or tape the numbers 1 – 6. In this activity, which is also described in a publication of National Academy of Science (1998) and in my application (Keyes, 2002), students

[3] Pigliucci's use of the term "strong inference" refers to John Platt's (1964) use of the term as a way to apply the inductive method in a more systematic and hence, more productive, manner.

are asked to make observations, raise questions, formulate a hypothesis, and provide some possible supports (evidence) for a hypothesis, which is generally stated as "The number X is at the bottom of the cube". This is a 'hypothesis' because the students are never shown the bottom of the cube and so they must formulate a reasonable "educated guess", to use the students' favorite definition of hypothesis. I have found this activity useful to address concepts such empirical observation, assumptions, inference, proof, and skepticism and their significance in science.

- The Necker Cube. Another activity I employ that is useful in showing the role of perspective and viewpoint in research is to use a Necker Cube. Any number of other well-know images of optical illusions can be used to discuss the significance of viewpoint, bias, objectivity, and fact in conducting research. (Two other common optical illusion images are the duck-rabbit and the vase-lady silhouettes). Using such optical illusions in class are not only fun for students but provide an opportunity for instructors to discuss the greater complexity of taken-for-granted beliefs such as the idea that science is totally objective or the view that a fact. The concept of assumption can also be discussed by using such visual aids. The well-known Müller-Lyer lines are also useful as a springboard to a discussion about assumptions and perceptions and how such concepts affect scientific research (Barnes, Bloor & Henry, 1996). Obviously, viewpoint or perspective influences science starting with the questions that are posed and how data is interpreted.
- Beyond the Text. It was noted above that students tend to trust the authority and truthfulness of textbook. They seldom question what is presented in textbooks. Hood (2006) employs a strategy that she calls "teaching against the text" to encourage students to question what is contained in textbooks. Hood encourages students to recognize that textbooks sometimes contain errors and some material in textbooks can be contested. Hood administers a True/False test to show how apparent 'factual' statements about qualitative research are often only partial truths. For instance, Hood notes that the statement "Participant observation is the field work method most commonly used by qualitative sociologists" is only a partial truth. She uses such True/False statements as a method to discuss other common misconceptions. Hood also has students find published examples of various types of qualitative research to discuss epistemological questions in research. Epistemological questions, Hood points out, are hardly ever directly addressed in introductory textbooks. Many students find that questioning the text leads to confusion and uncertainty because students have been socialized to accept the truth of science and what is contained in textbooks. Hood concludes that "teaching against the text" fosters critical thinking even if students resist.
- Critical Thinking Questions. Perhaps one strategy that may be sometimes overlooked is to simply ask students to apply the eight elements of reasoning proposed by the Center for Critical Thinking (1993). While many instructors already use these in various ways and degrees, using them consistently and often will help students gain a better appreciation of not only TSM but the actual content of the disciplines they are studying. The main elements that promote critical analysis include questions of: purpose, perspective, problem, evidence, assumptions, concepts, implications, consequences. These elements can readily be employed in a

number of teaching strategies in all disciplines (see for example, Keyes & Keyes, 2004). Indeed, this is a simple way to go beyond the text.

Conclusion

Teachers must go beyond the routine. We reinforce minimal understanding when we assume that students understand when they may be simply repeating words without given them deep consideration. Engaging students in deeper conversation can broaden the narrow views of TSM. Teaching techniques that help give students application opportunities require greater investment in time and energy. Given the structure of university and textbook organization this may mean sacrificing some content or some material for the gains in greater critical analysis. Perhaps textbooks are also in need of some revision since they continue the practice of simply parroting the definitions that all too frequently provide superficial views of TSM.

While teaching the scientific method, we should encourage students to develop a deeper understanding of research, even if that requires us to question how we ourselves present the methodology. Too frequently students have a narrow view of science, limited by the folk culture of science. For instance, students tend to equate experimentation and quantifiable data with science. This view spills over into the social science. The social sciences have an opportunity, because of the nature and complexity of their subject matter, to demonstrate that TSM entails more than the stereotypical and narrow conception students have of science being carried out in laboratories by people in white lab coats. The rather pervasive view promulgated in textbooks that science involves formulating hypotheses, controlling variables, and experimentation can be broadened by the social sciences. Bauer provocatively states: "That scientists in practice do not actually use the scientific method, and that the scientific method cannot adequately explain the successes of science, does not mean that the method is not worth talking about, that it is not worth holding as an ideal" (1992, p. 147). He further points out that science is a human activity and "the scientific method specifies some rules that, if followed, permit one to learn" (149). It is, therefore, a worthy endeavor for all teachers, including those in the social sciences, to not only pass on the vocabulary of science but to help students gain a deeper understanding and appreciation of its utility.

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