Barriers Against Interdisciplinarity: Implications for Studies of Science, Technology, and Society (STS)

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Interdisciplinary work is intractable because the search for knowledge in different fields entails different interests, and thereby different values too; and the different possibilities of knowledge about different subjects also lead to different epistemologies. Thus differences among practitioners of the various disciplines are pervasive and aptly described as cultural ones, and interdisciplinary work requires transcending unconscious habits of thought. The more those unconscious habits are explicated and the more we understand how the disparate characteristics of the various intellectual cultures are related to the necessarily different interests, values, and epistemologies, the more feasible becomes the goal of transcending thought habits. Two sorts of interdisciplinary effort seem to have been successful: specific, delimited problems have been solved by teams in what is actually multidisciplinary rather than interdisciplinary work, and new disciplines have sprung up at the intersections of existing ones. STS fits neither of those patterns. Can it nevertheless be viable?

Institutional factors are typically named as the culprits that impede interdisciplinary initiatives (Wolman 1977). Here I suggest that those institutional factors are not the actual source of difficulty but merely some of the symptoms; in fact, they stem naturally from the manner in which knowledge about disparate fields has grown, by necessarily and not arbitrarily different approaches.

The practitioners of the various disciplines show stereotypical differences over many things: lecturing style, design of curriculum, role of graduate students, and also political, social, and religious affiliations and beliefs. I suggest that those differences, too, stem at least in part from necessarily different

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training. In other words (e.g., those of C. P. Snow 1962, 1964), the various academic disciplines represent different cultures. Communication across them is impeded by a host of differences that are largely implicit. Communication and cooperation could be facilitated by making explicit what the differences actually are and how they stem from an initial concern with different subjects.

To be viable, STS needs not only to foster productive interdisciplinary interaction among its practitioners, it needs to persuade the rest of the wider society of its value. The stimuli that have brought STS into being need to be kept in mind. Useful products of STS should be promulgated.

As people trained in disparate disciplines attempt to work jointly, and particularly as they promulgate their findings to others, it may be necessary - at least initially - to eschew the sophistication that marks long-establishes disciplines.

Differences Among Disciplines

Disciplines differ not simply through being knowledge about different subjects, nor just because they happen to use different methods for getting knowledge. Were either the case, there would be no difficulty in doing interdisciplinary things. But only in science fiction and in pseudoscience (Bauer 1984, 228--95) is interdisciplinarity attainable as and when one wishes. Disciplines differ in epistemology, in what is viewed as knowledge, and in opinion over what sort of knowledge is possible. They differ over what is interesting and what is valuable. And the practitioners of the various disciplines have characteristically different attitudes and habits and manners---that is, they differ over matters that might at first seem quite unrelated to the practice of their disciplines.

Though we often talk globally of academe being engaged in the search for truth, "truth" means quite different things in different disciplines. "Even the concept of `truth' is completely different in the legal sense than . . . in the scientific sense. Scientists (and engineers) believe implicitly in certain absolute truths, and further believe that given enough time and effort the ultimate truth can be found . . . For the attorney . . . there often is no absolutely determinable truth" (Bromberg 1984). Not only for the attorney is that the case, but also for (at least some) philosophers, sociologists, and others.

These various attitudes toward truth entail different opinions over what things can be established with any degree of certainty and what that degree is, and they are associated with correspondingly different attitudes to such more mundane things as how to choose research projects, how to evaluate evidence, and much else. For example, lawyers and scientists take typically different attitudes toward what can and what cannot be established through the testimony of eyewitnesses, and the lawyers' approach simply cannot usefully be adopted in science (Bauer 1986a, 55--8). Or again, historical truth is necessarily different for historians and for scientists (Harrison 1987). Different sciences tolerate different balances between fact and speculation, and display varying tendencies to indulge in simple explanations. Concerning the extinction of dinosaurs, for example, paleontologists on the whole do not support the physicists' notion that a single catastrophic impact is sufficient explanation (Browne 1985; Sloan et al., 1986). Even among sub-disciplines one finds striking differences over what makes sense and what is useful. Thus organic and inorganic chemists differ generally over the "best" representation of the periodic table, that classification of the chemical elements acknowledged as fundamental by all chemists (Sevenair 1987).

My thesis research was to measure the quantum yields of photochemical reactions, and I learned from my mentor that experimental accuracy and reproducibility were paramount. But one of my friends had the task of making ab initio calculations of dipole moments, and his work was highly praised even though the results fitted not at all well with the experimental values---so *he* learned that experimental accuracy and reproducibility were anything but paramount. Thus experimentalists and theoreticians learn different things, even contradictory things, about what "science" is, about what the criterion for good work is, about what an advance in knowledge is, about the relative importance of experiment and of theory.

Scientists learn that nature offers predetermined categories of objects: Thus "metals" and "nonmetals" differ in some very real sense, and the periodic table of elements reflects realities that have nothing to do with observations or speculations by people. Social scientists, by contrast, learn that (social) facts are constructed, not discovered: Thus, "democrat" and "fascist" are humanly invented and defined labels, and people may well differ over whether those terms are useful ones---or, even if they are, how they might apply in any given situation. One can be wrong in calling something a metal in quite a different manner than one might be charged with error over calling someone a fascist. It is possible, easy even, to be objective about whether a thing is metal, and it is possible to be objectively right or wrong about it. It is difficult, perhaps even impossible, to be objective over whether someone is a fascist (and since it is difficult or impossible, the practitioners label it meaningless and claim that objectivity is an illusion rather than a possibility).

Practitioners of the various disciplines differ not only in epistemic matters that pertain so directly to the contents of their fields, There are characteristic differences, too, in what might seem unrelated things, for instance, the use of notes while lecturing. Scientists typically speak with relative informality from brief notes, whereas humanists typically lecture by reading a complete text. And that tangible difference surely entails a host of others: the criteria by which one judges how good a lecturer is, how one thinks about the task of preparing a lecture and how much time one devotes to it, how important one believes it is to have secretarial help (or a word-processor). A speaker who gives a colloquium without referring to written notes arouses admiration in an audience of scientists, but in an audience of humanists, a suspicion that the talk may not be very profound. The scientists recognize how very much time went into preparing the talk, whereas the humanists suspect that little time was put into preparation - the lecturer obviously did not spend the time to prepare a proper text!

One is trained to these various attitudes from the beginning. Professor Ernest Ritchie, teaching organic chemistry at the University of Sydney, always carried to class a crumpled piece of paper, barely larger than his hand, which he would glance at occasionally as he covered the board with names and equations for innumerable reactions. On the last day of term, he forgot his notes on the lectern, and we rushed to see just how he had managed to fit all that material onto such a small piece of paper. We found it to be totally blank. Scientists, but not humanists, can savor *without any explanation* that piece of humor or one-upmanship.

Those different styles in lecturing reflect appropriately different views of humanists and scientists as to what scholarship involves. Scientists discover truths about nature, and their task when lecturing is simply to lay out those facts. One who has really mastered the current state of knowledge can lay it out for others "out of his head"; he needs notes only to remind him of what to mention next or when to insert a joke. In the humanities, by contrast, ingenious originality of thought and subtle sophistication of expression are more to the point than any recitation of facts. Indeed "facts" in the humanities are almost by definition mundane. For professors of English, literary criticism - theorizing, interpreting - is the highest form of scholarship, in contrast to the factually aimed work of textual editors or bibliographers

Again, one may hear a philosopher or a historian remark during in subsequent discussion, "the paper argues. . .," making a clear distinction between the paper and its author. Such a distinction would be unthinkable for a scientist, who is responsible for the accuracy - the *factual* accuracy, which is all that counts - of whatever he says in a lecture or writes in an article.

There are many other such differences between humanists and scientists. The former believe that students should take a considerable number of upper-level courses during their studies, whereas the latter know that to be impossible because students must take a large number of lower-level courses to prepare them for advanced work in their special field. Upper-level science courses have prerequisites whereas most of the upper-level courses in the humanities (or in the social sciences) can be taken without prior acquaintance with the subject. Scientists are typically incredulous when they discover that, but it fits naturally with the circumstance that some evidence of original thought is from the beginning expected of students in the humanities, whereas students of science are expected to learn facts and techniques and to defer their questioning until they are ready to begin research. Labeling as "upper-level" courses in the humanities signifies that a higher degree of sophistication of thought can be expected of the students, whereas upper-level courses in science mean that the students can be expected to know a larger amount of facts and theories and methods.

Scientists, but not humanists, appropriately adopt a reductionist view arrived at inductively. One simply cannot learn chemistry without some physics and mathematics, or biology without quite a lot of chemistry (and the necessary physics and mathematics), and so forth. It is *Nature,* not science or scientists, that entails reductionism. Humanists, by contrast, are aware that choices about a curriculum, say, are theirs to make; they are not predetermined for them by Nature. So in academic arguments over curricular and other matters, scientists tend to adopt a dogmatic stance - they think their opinions reflect facts about the world - whereas humanists and social scientists tend to see such disputes as matters of relative power and status - they believe that the world offers no useful factual guides to action on such issues.

Practitioners of the various disciplines differ over much more than academic matters. One can, for example, characterize some groups as typically conservative in political and social affairs and others as typically liberal or progressive. Thus Snow (1964, 64) remarked that organic chemists are typically conservative whereas biochemists are not, during the 1960s the student revolutionaries were supported by practitioners of some disciplines much more than by practitioners of others, attitudes toward faculty self-governance are very different in a College of Business and in a College of Liberal Arts, and so forth. The significant point is that differences among disciplines go very far beyond any purely substantive concern with different sorts of subject matter; yet those differences are, to a certain degree, *entailed* by concern with those various subjects, even though the connection may not always be obvious at first glance. So it was apt indeed for Snow to characterize the differences between scientists and humanists as marking different cultures. In each of those two cultures, "without thinking about it, they respond alike. [For instance, to the use of notes by a speaker, or to suggestions that many upper-level courses be required for a bachelor's degree, or to the platforms of the conservative and liberal political parties.] That is what a culture means" (Snow 1964, 17). Scientists "have the future in their bones" (Snow 1964, 16); nonscientists are "tone-deaf" with respect to science (Snow 1964, 20). The attempt to communicate across the cultures is "as though listening to a foreign language of which one only knows a few words" (Snow 1962, 90).

Though Snow did not argue the matter in any detail, he was clear that these cultural differences are in part entailed and not arbitrary: "The reasons for the existence of the two cultures . . . rooted in social histories . . . personal histories . . . the *inner dynamic of the different kinds of mental activities*" (Snow 1964, 27); we are "more than we think children of our time, place and *training*" (Snow 1962, 62) (emphases added). And he was clear that these cultural attributes are firmly entrenched and strong, so that, for example, the commonalities among scientists transcend their diversity in social class, politics, or religion.

Interdisciplinarity

Snow's purpose was served by emphasizing "two" cultures, though in his text he mentioned a third and a fourth, and explicitly acknowledged the existence of many. The present purpose is better served by considering each academic discipline as a separately identifiable culture. The disciplines evolved and flourished as their individual quests for knowledge prospered. Departmentalization, specialization, and sophistication are concomitants of that success, necessary concomitants and not arbitrary choices self-consciously adopted by self-seeking guilds of competing entrepreneurs of knowledge. For each discipline, there is a natural set of corollaries embracing not only matters clearly tied to the subject, for instance, epistemic or methodological stance, but also such apparently unrelated matters as political affiliation and style of behavior. In other words, each discipline can be aptly viewed as a *culture*.

Little has been done toward elucidating the characteristics of these separate cultures. Though there exist some descriptive, anecdotal accounts (Adams [1976] 1988, chap. 3; Brownlee 1984; Martin 1988, chap. 16) and at least one explicit study (Roe 1952), in the main these cultural differences are recognized only within academic folklore, usually in a jocular fashion. But those differences do underlie some events that would be difficult to explain on another basis and that are not necessarily humorous or without significant consequence - that a mathematician characterizes as pseudo-science the work in political science of a candidate member of the National Academy of Sciences (Sherman 1987), for example; or that sociologists snicker and roll their eyes when, in a purposefully multidisciplinary setting, a philosopher confesses to a modicum of philosophical realism.[1] Thus in the realm of the intellect and its variety of cultures, we are still at the primitive level of tribalism, complete with xenophobia, much more likely to wage war on other tribes than to regard them as equals worthy of meaningful collaboration.

What sort of interdisciplinary work might then be possible?

By seeing disciplines as cultures, one recognizes that a field or subject – its knowledge, methods, theoretical approaches - cannot be separated from its practitioners. Outsiders cannot properly practice an intellectual discipline just as foreigners find it difficult to assimilate into a national culture. Even more to the point, single elements of a culture cannot be separated from it and then merged with elements from other cultures: Shintoism fits just as little with the English way of life as cricket does with the American; the American style of democracy cannot be grafted onto a Stone Age culture; and so on and so forth. Just so in the realm of the intellect. Experimental chemistry cannot be practiced from the viewpoint of a theoretician; it is not even possible to visualize what that might mean (other than poorly done experimental work). So what could it possibly mean, to do chemistry from a sociological viewpoint, or sociology from a chemical one, or either of them from a viewpoint that somehow is an amalgam of the two? What sort of amalgam could that be? Once again, it is in science fiction or in pseudoscience only that an individual or group can radically and quickly synthesize the fruits of several disciplines while standing outside (and therefore to some extent antagonistic to) those disciplines. Thus Velikovsky imagined that he could deploy and employ astronomy, geology, history, and other disciplines in ways with which the professionals in those fields disagreed - and what he produced was only scientific gibberish (Bauer 1984, 228--95).

One of the most frequently cited "interdisciplinary" successes, the design and manufacture of the atomic bomb, in fact required little if anything that could properly be called interdisciplinary. The physicists, engineers, and soldiers worked much in their accustomed styles, contributing useful bits to the overall task - a multidisciplinary success, but not an interdisciplinary one. Moreover, the task was a quite concrete, specific, and limited one.

Truly interdisciplinary successes are the emergence of such new disciplines as biochemistry or molecular biology. But those called for no major alteration of underlying epistemologies or methodologies. Chemists and biochemists do not differ over the possibility of discovering true theories of nature, for instance, nor over the need for reproducibility of experimental or observational results, Nor do they differ too much over what sort of demon stration will count as reproducibility, though they do differ, of course, about such things as how to deal with complex systems (or, more fundamentally, over whether it makes sense to do so).

STS fits neither of these patterns of success. The task is not to solve a specific and limited problem through resources from several fields, nor is there much common epistemic ground among practitioners (or prospective practitioners) of STS. If scientists and technologists and humanists and social scientists are to contribute - as is the hope - to STS, then people who believe that an external reality exists to be discovered and described must work with those who believe that science is limited to constructing models that ineradicably reflect characteristics of the model builders; those who believe it *wrongheaded not to assume a discoverable external reality* must work constructively with those to whom it is *wrongheaded to assume such discoverability.*

An Analogy with Languages

The division of the intellectual realm into disciplines is analogous to the division of humanity into different language groups. Just as languages are distinguished more by grammar and syntax than by vocabulary, so disciplines are distinguished more by theoretical and methodological points of view than by the "facts" they contain. Some languages support concepts that are simply not available to others, for example, the well known difficulty that speakers of English have in comprehending *Gemütlichkeit* or *Sympathisch*, or that Germans have in comprehending "that's not cricket." In a similar way, the sociologist cannot really understand what the scientist means by “objective”; and the scientist cannot understand how the sociologist can think of knowledge as "constructed." Just as in languages the vocabulary cannot be entirely separated from the grammar, the syntax, or indeed the national culture, so in the disciplines "knowledge" cannot be isolated from the conjugate methods, the theories, or indeed the history and practice of the field.[2]

A first requirement for useful interdisciplinary effort might be the acknowledgment that different languages are merely different, not unequal. Some languages, of course, are better at some things than are others. Japanese is not very good at the sort of categorical distinctions necessary in science, but it is exceptionally fine for recognizing subtle social distinctions or for poetry in the haiku format. Just so are the different disciplines better for different purposes. That is why STS now demands interdisciplinary effort – because science and technology are matters of'epistemic inquiry, and *also* matters of industrial and commercial application, and *also* essential components of any decent education. *Also* they are social activities, and *also* they have histories that have shaped their nature and must therefore be comprehended. STS is needed because the philosophical descriptions of science are of only one aspect of science, and the historical case studies reflect only some aspects of science, and the sociology of science captures only some aspects of scientific activity, and because science policy is empty or misleading without an authentic feel for the nature of science. So an essential requirement for interdisciplinarity is the recognition that each discipline has an appropriate and necessary role, complementary to and not superior or inferior to that of another.

Another related requirement may be the explicit acknowledgment that, within their own spheres, the individual disciplines remain justifiably paramount. Not only in science fiction or in pseudoscience but also in certain parts of academe one encounters the claim that interdisciplinarity is desirable *in itself*. But those claims seem weak when one admits the difficulties. Has it even been established what truly interdisciplinary effort would be like, let alone that it is possible? But beyond that, it is not even clear that multidisciplinary work, which is certainly possible, is necessarily desirable. George Bernard Shaw (1945, xxvii) reminded us that Mezzofanti, master of 58 languages, had nothing of interest to say in any of them. Like any new venture, an interdisciplinary one must demonstrate its value and not expect to be appreciated before that event. A priori it is not unreasonable for academe to suspect that "interdisciplinarity" may sometimes be a cover for dilettantism or worse. Some interdisciplines, after all, have seemed successful for a time only to wither away again, for instance American Studies (or area studies generally). So it might make sense for STS to insist that it is badly needed *for specific reasons* and to eschew interdisciplinarity as a cause in itself, as it should also eschew criticism of *disciplinary* behavior, such as departmentalization. The real barriers are not these institutional factors over which we expend so much emotion but the intellectual ones, and what stems from them. We have barely begun to recognize these, let alone explore them.

The difficulty of interdisciplinarity strikes home as one tries to imagine what *interlingual* speaking might mean. Though occasionally loan words from one language have been adopted into another, more usually one shudders or laughs at the immigrant who mixes the vocabularies of different languages or uses the grammar of one with the vocabulary of another. Dialects (subdisciplines) of course do arise naturally and may grow into full-fledged languages (disciplines); but self-conscious attempts to invent a universal language - Esperanto, Ido, Interlingua, Novial, Occidental, Volapük - have produced only hopeful monsters, short-lived curiosities. A requirement for successful interdisciplinarity may well be that one fully acknowledge the difficulties.

Granted that truly interlingual speaking may not be possible, one begins with multilingual effort; and children growing up in such an environment may learn to communicate more meaningfully across languages than adults are able to. So it is that STS must begin with enthusiasts drawn from various disciplines, as a multidisciplinary effort, but may come to assume genuinely interdisciplinary aspects as (graduate) students pursue their studies in that environment and learn to transcend the barriers that they perceive among their mentors.

Perhaps one of the most significant lessons for STS might come from contemplating the difference between linguists and native speakers. The natives may be quite ignorant of the history, development, and affinities of their language; they may know nothing of grammatical or syntactical rules, and they may habitually "make mistakes" from the viewpoint of those "rules"; but the natives surely have an authentic feel for what communicating in their language is all about, a better feel than any linguist can have for the organic connection between the language and other aspects of the culture. It is therefore not only impolite for linguists to inform the natives that they are making mistakes as they talk, or that their communication lacks certain important elements if it is to be significant: the linguists are almost certainly *wrong* when they believe such things to be the case. Now in STS, scientists and technologists are the natives. They may be entirely ignorant of what philosophy (rightly) has to say about epistemology, or what sociology (rightly) has to say about interests or social stratification, or what political scientists (rightly) have to say about negotiating policy; but (some) scientists and technologists nevertheless have an authentic feel for what they do that is not vouchsafed to those who have only practiced history or philosophy or sociology.[3] It is not only impolite and counterproductive for STS to criticize scientists for their reductionism, or for being only human, or for not being perfect in that fraud does occasionally get perpetrated within science. Such criticisms stem from the observer's lack of authentic understanding of the nuances of the scientific culture, from the use of that observer's *model* of what science is (or ought to be!) and not from actualities of science and scientists. All too often one finds linguists or anthropologists adopting a stance of superiority over the ignorant natives, unaware that those natives may be in no way less intelligent or perceptive; and then linguistics or anthropology may go astray for decades through the acceptance of myth as fact - as with Samoa and Margaret Mead (Levy 1983).

Toward Success for STS

So much for difficulties within STS, impediments to successful joint endeavor among people from disparate fields who have already agreed in principle that the jointness is worthwhile. It is also necessary that the enterprise be approved from the outside, by academe and its current disciplines and by the wider society and particularly the institutions that fund scholarly activity. Why has there been interest in establishing Science and Technology Studies? What do people hope for from it?

One long-running source of STS is the nineteenth-century captivation with the successes of natural science, which led to the belief that "scientifically" governed and aimed societies and people could be not merely successful, but successful even in wished-for directions; consider as exemplar H. G. Wells, perhaps. Within that stream, there is a current of Marxism - thus, J. D. Bernal is sometimes identified as the person most central to the beginnings of the STS movement in Britain. But perhaps the strongest impetus comes from an undercurrent of scientism that tends to grip those trained within science, be their politics of the left, the middle, or the right.

With the Second World War came practical demonstrations that society needed to take explicit account of the impact of science and technology. Indeed, it was this experience that enabled some people to notice the inherent difficulties and some of the cultural differences, since scientists were typically incredulous earlier that such things as bombing strategy could be decided not on the basis of whatever evidence might be available but on the basis of which arm of the military services could exert a stronger and entirely self-interested influence (Zuckerman 1978, chap. 7). Subsequently, others have noticed that it is fortunate if a scientist happens also to become an effective political adviser or manager, for training within science tends to make one impatient of the greasing of channels and self-conscious political maneuvering that social systems require even to accomplish something so obviously necessary as the elimination of a federal budget deficit. On the other hand, those to whom it comes naturally to engineer social consensus usually suffer the illusion that scientists can deliver anything that is asked, provided only that the right carrots and whips are plied. Thus it is widely agreed that society needs science and technology and also needs, as far as possible, to guide or control them. But it is not agreed how to achieve that or who is best qualified to tackle the matter.

Those are the roots of what one might call the practical or applied side of STS, seeking to make science and technology tangibly useful to society at large. The theoretical or fundamental side of STS grows from the recognition that science cannot be understood from a single disciplinary viewpoint. Thus philosophers were forced to realize that science is not only a matter of facts and logic, and one began to see programs established in history and philosophy of science, and the like. Kuhn's *The Structure of Scientific Revolutions* (1962) is usually acknowledged as marking this watershed.

Within academe, some STS programs had their genesis in the latter, academic stream, among humanists and social scientists. Others grew from the attempt by sometime scientists and engineers to explicate those enterprises to others; on occasion they were joined by political scientists. The latter programs tend to have (even) less credibility within academe, whereas the former tend to become so focused on research that they neglect the task of educating outsiders. Both streams of activity are needed; and a conscious effort to promulgate useful findings of STS may be the best way of ensuring the viability of even those STS programs whose main activity is theoretical. Such outreach activities may also be useful in forcing STS practitioners to come to agreement among themselves over what the axioms of STS are.

Useful Insights From STS

Below are listed a few of the things that all educated people ought to know about science, technology, and society. Some of them are known to and taught by one or another discipline or subdiscipline, but no other endeavor than STS seeks to encompass them all. Yet they are all important to the wider society and have immediate applications.

1. Science and technology are quite different things. Therefore, don't assume that advances in science will necessarily or always lead to important technology.

2. Future knowledge is unforeseeable: that is, future science is unforeseeable. Therefore, it is paradoxical for a National Science Foundation to claim to support potential breakthroughs by awarding funds to "projects" judged by reviewers on the basis of how likely they are to succeed.
3. While specific technologies can sometimes be foreseen, the implications of technology are unforeseeable. However, it is almost certain that any new technology will have *unforeseen and unforeseeable* consequences.
4. Single, even apparently simple factors lead to a multitude of consequences because living systems and societies harbor complex interrelationships. There is no such feasible thing as "only" wiping out mosquitoes, for example - other living species will be affected; nor can one "only" clean up the environment – the standard of living measured in conventional ways will be lowered; nor will there be a miracle drug to lower blood cholesterol and leave the rest of a person working as before; nor will it make sense to transplant organs until the immune system is understood rather than seen as an enemy to be immobilized.
5. Some of the most worrisome social questions cannot be answered by unequivocal experiment; the best available evidence will always be statistical; statistical inferences always have a residual uncertainty; correlations do not signify causation.
6. Science is fallible. Facts are theory-laden. Such contingent factors as individual psychology, social forces, and historical influences have their effect on the speed and direction of progress of science. Nevertheless, science is enormously reliable. One needs to recognize and respect the distinction between science at the frontier, where much is contingent and uncertain, and science in the textbooks, where little is uncertain (within the boundary conditions under which the knowledge was gained) and almost nothing remains contingent on psychological or social or political or religious factors. Within the STS community itself this point is not widely enough understood (Bauer 1986b): The humanists and social scientists understand the fallibility and contingency of science at the frontier but have little if any feel for the enormous reliability of long-established science, whereas the engineers and scientists know the enormous reliability of their texts and reference works without realizing that the same reliability does not pertain to recent discoveries, let alone to projections made by individuals.
7. Science is a social activity. Therefore, it is inherently conservative. Breakthroughs occur *despite scientists*, not because of them: they occur when reality refuses to mold itself any longer to current theories. The reliability of science and the conservatism of science are inextricably linked.

All these points are of course quite simple ones and draw on no deep understanding of philosophy of science or history of science or any of the other relevant specialties; they must seem quite mundane in comparison to the issues that are typically discussed in specialty journals. But that is how it must be when a new discipline seeks to establish itself: It must begin with only those things that are held in common by all practitioners; and when the individual disciplines are as disparate as in STS, things are bound to seem rather superficial at first. Nevertheless, if even a few of these insights and their corollaries were acted upon, there would be immediate and tangible benefits to society. Admittedly, acceptance of these realities is hampered by the fact that they run counter to popular wishful thinking. STS surely has an important role to play in educating to these realities and in discovering more detail about the nature of science and technology and their interactions with other human institutions.

Notes

1. At the closing plenary session of the Conference on History, Philosophy, and Social Studies of Biology, Blacksburg Virginia, June 16-20, 1987.

2. That point is germane to the theory and practice of education. There is a misguided notion that emphasis on "facts" neglects training of the mind to be critical or that it involves a different realm from that of "values." That notion has had disastrous consequences as applied to American children. That knowledge can never be "mere" is continually stressed in *The Underground Grammarian* (P. O. Box 203, Glassboro, NJ 08028); see also Mitchell (1981, 1984).

3. Within STS, here are some examples of studies that must seem to the natives beside the point or missing some essential points. (Quotations are from the Abstracts of the 1987 Annual Meeting of the Society for Social Studies of Science, *Science and Technology Studies* 5:74-6.)

> *Science-Ads* . . . Science is business in disguise. Scientists sell knowledge-products as commodities in a competitive market; their livelihood depends on it. A variety of buyers (industry, the state, venture capital) choose to buy science . . . Scientists . . . exchange promises for cash (facilities, jobs, credibility, etc.) . . , science *is* a commodity not unlike deodorant or mouthwash . . .

> This essay describes the performative interaction among participants at the 50th anniversary of the first X-ray protein photo, and interprets it as a social ritual . . . the invitation and the program . . . [are] textual strategies designed to mobilize the "tribal assembly" for a succession rite in which three successor heroes divided among themselves the legacy of a venerated "ancestor."

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