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Science and Technology Studies

This title names a heterogeneous body of research, scholars, journals, professional associations, and academic programs that focus on the history, social organization, and **culture** of science and **technology**. Begun in the 1960s in response to the recognizable growth in science in the contemporary world and to the educational and economic policy implications of this explosion of scientific research and development, Science and Technology Studies (STS) also responded to issues of public responsibility that seemed to be engendered by technological innovation.

Significant accounts of the work of scientists, the accumulation of scientific knowledge, and the impact of technological innovation had been produced in each of the **social sciences** from their distinctive disciplinary perspectives by the 1960s, generating a "focused confluence" begging for integration, according to David Edge in "Reinventing the Wheel" (*Handbook of Science and Technology Studies*, 1995: 3–24). Across the diverse research traditions, there seemed to be, however, a shared or received view of science as the work of great minds, usually male, discovering nature's hidden patterns and mechanisms. This is often viewed as a bounded activity in which science impacts society, technology – as applied science – develops linearly from (basic) science, and the entire process is regarded as a value-free, amoral enterprise that is legitimated by the claims both that its truths exist independent of, and prior to, any social **authority** and that it provides the grounds of human **progress**. This "internalist" account describes an essentially autonomous and asocial process consistent with positivistic philosophies of science as a self-regulated search for timeless, universal, irrefutable facts. Facts are themselves understood, in this received or traditional conception of science, to exist independent of the procedures for making or discovering them. Sal Restivo in *Science, Technology and Society* (2005) has argued that "Scientific facts were considered to exist in a realm outside of the blood, sweat and tears of our everyday sensual and material world, outside of history, outside of society and culture."

By the 1960s, however, few realms of human action were immune from acknowledgment of their historicity, including science. Within each of the traditional social science disciplines (history, philosophy, sociology, economics, anthropology, and political science), germs of a more complex understanding of science and technology were developing. Despite diverse theoretical, pragmatic, and disciplinary sources, science and technology studies seemed to force an orienting consensus that science is a social **institution**. Although it had long been clear that science and

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technology impact society, an impact that was already documented in historical scholarship and economic development, science and technology studies began by exploring the ways in which social forces constitute not only the context of science (for example the organization and dissemination of science) but also the content and substance of scientific knowledge itself.

Importantly, science and technology studies developed not only a more complex but also a more critical stance towards science and technology, emerging simultaneously with periods of intense public skepticism towards the roles of science and technology as an aspect of the growth of anti-military sentiments against American involvement in the Vietnam War in the United States in the 1960s and 1970s, and the growing anti-nuclear and environmental movements in the United Kingdom and Europe in the 1980s. The constructivist position that social forces constitute not only the context but also the content of science developed first in Europe and spread from there. Alongside this more socially engaged scholarship (for example in Donald MacKenzie's "Tacit Knowledge, Weapons Design and the Uninvention of Nuclear Weapons," *American Journal of Sociology*, 1995: 44–99), research moved away from the more traditional periodization and research foci (for example the scientific revolution, Darwinian revolution, or Quantum Revolution) that occupied historians of European science. As STS develops, scholars become interested in science outside of Europe and also more interested in activities not heretofore categorized as science by contemporary scientists, such as the alchemical interests of both Newton and Boyle, and the relationship of these to the works that are taken to have made the scientific revolution, or the ways in which mathematical equations are understood in some African cultures (Betty Jo Teeter Dobbs, *The Foundations of Newton's Alchemy*, 1975; Lawrence Principe, *The Aspiring Adept: Robert Boyle and His Alchemical Quest*, 1998; Helen Verran, *Science and an African Logic*, 2001). No longer do scholars regard it as appropriate to isolate the elements of scientists' work that have over time proven useful and scientifically productive, discarding what modern science has rejected as aberrational or simply wrong. STS attempt to produce fuller, more comprehensive and complex accounts of science, its methods, and its subject matter.

By the 1980s, it was well understood, and in some scholarly networks taken for granted, that science is in this regard the same as all other human activities, a socially constructed phenomenon: the product of collectively organized human **labor** and decisionmaking.

> Facts do not fall out of the sky, they are not "given" to us directly, we do not come to them by means of revelation . . . [W]ork is embodied in the fact, just as the collective toil of the multitude of workers in Rodin's workshop is embodied in *The Thinker*. This is what it means to say that a fact is socially constructed. (Restivo, 2005: xiii).

This does not mean that any statement can secure the status of scientific fact; social construction is not a recipe for cognitive solipsism or moral relativism. Nor does it mean that scientific facts are completely arbitrary accidents. It means only that scientific facts are contingent: the ways in which a fact is produced – the choice of topic, location of research, the constraints of resources, the accumulation of empirical evidence, the transparency of methods – are part of the constitution or construction of the fact. Scientific facts are produced under constraints that vary historically and culturally; thus scientific inquiry is both enabled and constrained by what is already known, by technological capacity and the material resources that are available, and human capacity for work, imagination, collaboration, and communication. Those constraints shape the content of the science as well as the process of producing that content.

Considerations of organization, resources, and human capacity seemed obvious with respect to technological innovation, but in the traditional disciplines were usually relegated to the boundaries of science or the social conditions of its making. STS rejected the notion of a natural or fixed boundary between science and its context. What became known as "boundary work" – the discourses and practices of institutional **legitimacy** and exclusion – became a central focus of STS research tracking the human transactions – symbolic and material – that shaped scientific facts and membership in scientific **communities** (for example in Thomas Gieryn, *The Cultural Boundaries of Science*, 1999). Similarly, any hard and fast distinction between basic science and applied technology became difficult to sustain, once the work of scientists and engineers is closely observed. The advance of modern physics, for example, is described as a productive collaboration between theory, instrumentation, and experiment in Peter Galison, *Image and Logic* (1997). Finally, any hard and fixed division between the disciplinary approaches to the production or reception of science began to merge in important studies. Steven Shapin and Simon Schaffer's influential book, *Leviathan and the Air-Pump* (1985), encouraged scholars to move among the historical, anthropological, and sociological approaches to the study of science and technology.

Yet this social constructivist orientation probably claims more than some in the field would admit, and has been the source of shared interests as well as extended controversy among science and technology scholars and between the field and the practitioners they study: scientists, engineers, and policymakers. As in any other field of cultural production, as described by **Pierre Bourdieu**, STS is constituted more by its oppositions and debates than by any shared theoretical **paradigm**, set of research questions, or canon of readings. However, STS may be more fractious than many other scholarly fields or interdisciplinary engagements. Because STS scholarship takes the creation of knowledge as its subject of study, it has been hyper-reflexive about its own knowledge production practices, leading to extended yet insightful debate. Sometimes referred to as the science wars, these scholarly disputes suffused much of academia in the 1990s where they went by a more generic label as culture wars. One line of cleavage developed about the strength and depth of the constructivist position and the sufficiency of internalist histories of science. Another derives from the conjunction of science and technology within the same intellectual rubric, and yet other lines of cleavage develop from epistemological debates and professional competitions among the constituent disciplines. This self-reflexive critique in a heterogeneous joining of topics and disciplines has produced an abundance of shorthand expressions and acronyms to describe the distinctive camps and orientations. For example, some observers distinguish the scholarship of STS from the subject being studied, the latter a subject that can be studied via STS or through any traditional discipline such as history, sociology, or philosophy without adopting any particular epistemological position with regard to the social construction of science. Those who focus on the sociology of scientific knowledge (SSK) distinguish themselves from those who examine the social construction of technology (SCOT) or the social history of technology (SHOT). The STS coalition probably bespeaks more about the marginality of science and technology to the central concerns of the constituent disciplines than to any necessary or comfortable marriage between the study of science and of technology or across the disciplinary perspectives. Because the history, social organization, and logic of science has been a topic of minor interest for each of the disciplines – in comparison, for example, to concerns about state development, inequality, freedom – scholarly communities addressing science and/or technology in each discipline were relatively small and perhaps particularly guarded.

Nonetheless, the divergent perspectives and heated debates have energized the field, producing an abundant literature in books and academic journals (for example *Social Studies of Science* for science studies generally, *Isis* for the history of science, *Science, Technology and Human Values* covering contemporary science, policy, and culture, *History and Technology, Science in Context, Minerva, Osiris, Technology and Culture, Studies in History and Philosophy of Science*, and a wide range of specialized and regional publications such as *Metascience, Science Studies, Knowledge and Technology in Society, Public Understandings of Science, History of Science, Philosophy of Science, British Journal of the Philosophy of Science, British Journal of the History of Science, Science for the People*, and *Science Technology and Société*); a substantial network of professional associations (for example the Society for the Social Studies of Science, Society for the History of Technology, ICOHETEC [International Committee for the History of Technology], HSS [History of Science Society], IASTS [International Association for Science, Technology and Society]); and dozens of departments offering undergraduate and advanced degrees in STS.

STS research covers an enormous array of topics, most of which can be subsumed within two very general rubrics: (1) the institutionalization, reception, and appropriation of science and technology; and (2) the production of science and technology. With respect to the first aspect, interest in science and technology policy animated some of the first STS studies in the 1960s and led to a flourishing industry on scientific and technological controversies (for example Dorothy Nelkin, *Controversy, Politics of Technical Decisions*, 1979; Nelkin, *Atom Besieged*, 1982; and H. Tristan Engelhardt and Arthur L. Caplan, *Scientific Controversies*, 1987). Such work exposes the divergent theoretical assumptions, rival experimental designs, and contrary evidentiary interpretations, at the same time displaying the communally developed procedures for reaching closure on debate to restore continuity and consensus (Harry H. M. Collins and Trevor Pinch, *The Golem: What Everyone Should Know About Science*, 1993, 1998; *The Golem at Large: What Everyone Should Know About Technology*, 1998). Other lines of research in this general rubric focus on science institutions and funding; science **education** and public understandings of science; and, technological innovation, planning, and assessment. Closely related are studies of the role of science and science advising in government (for example Chandra Mukerji, *A Fragile Power*, 1989; Sheila Jasanoff, *The Fifth Branch*, 1990) and the role of scientific evidence in law (such as Roger Smith and Brian Wynne, *Expert Evidence: Interpreting Science in the Law*, 1989; Sheila Jasanoff, *Science at the Bar*, 1995; and Simon Cole, *Suspect Identities*, 2001). Using science to make policy, law, and property constitutes a thick strand of STS scholarship (see **law and society**). Since the 1980s, when American law changed markedly, allowing the results of publicly funded research to be patented and licensed, the institutional and distributional issues associated with technology licensing and transfer have been the subject of extensive research. These topics were present in the pre-STS work, primarily in political science and policy studies. STS contributed a critical dimension, revealing and unpacking the embedded, often unreflective claims of scientific expertise in law and elsewhere; at the same time, research explores the ways in which such expert **authority** is constructed and legitimated in and through government policies and programs (for instance in Brian Wynne, *Risk Management and Hazardous Wastes*, 1987; or Stephen Hilgartner, *Science on Stage*, 2000). STS scholars also study public and private systems of risk analysis in such diverse fields as weapons, environmental management, and financial **markets** (for example, Donald MacKenzie, *Inventing Accuracy*, 1990; Mackenzie, *Mechanizing Proof: Computing, Risk, and Trust*, 2001; Hugh Gusterson, *People of the Bomb*, 2004). Some, not all, of this research adopts a distinctly progressive, democratic stance, worrying about the consequences of concentrated expertise and public exclusion from critical decisions and the public responsibilities of science. This is an outgrowth of movements such as Science for the People that emerged as organized opposition to the American war in Vietnam; the movement and publications continue to this day in studies concerning such issues as genetically modified foods, explosion in the use and marketing of pharmaceuticals, as well as global warming and worldwide environmental degradation, unplanned growth, resource depletion, and **inequality**. Other works look at the human–machine interface from the point of view of instrument design as well as the role of technology, for example computers, in human relations and development (Sherry Turkle, *The Second Self*, 1984), while yet other research focuses on human relations with animals or nature in general (for example Donna Haraway, *Primate Visions*, 1990; Bruno Latour, *Politics of Nature*, 2004). In essence, this thread of STS scholarship marries in-depth technical knowledge of particular scientific fields or pieces of technology with examinations of the public and private uses for business, management, government, and interpersonal relations.

The second general rubric of STS research looks more centrally at the production of science and technology than at their appropriation, distribution, regulation, and use. Beginning in the 1970s, anthropologists and sociologists undertook closely observed, ethnographic studies of laboratory practices, processes of scientific discovery, and technological invention. Subjecting scientists, and later engineers in work groups, to the same scrutiny and in-depth analysis of social organization, culture, and **epistemology** that anthropologists had long applied to small-scale, often pre-industrial **societies** and human **groups**, STS researchers produced rich descriptions of the unarticulated and often tacit understandings that made science and scientists. In this way, they demonstrated that science is not a distinct realm of **social action**, but is like other social settings, rife with conflict, compromise, pragmatic adjustments, and **power**, as well as taken-for-granted habits that make social settings transparent and familiar to socially competent members but alien and uninterpretable to non-member outsiders (**Bruno Latour** and Steve Woolgar, *Laboratory Life*, 1979; Sharon Traweek, *Beamtimes and Lifetimes*, 1988; Karin Knorr-Cetina, *The Manufacture of Knowledge*, 1981; Michael Lynch, *Art and Artifact in Laboratory Science*, 1985; Lynch, *Scientific Practice and Ordinary Action*, 1993; Harry Collins, *Changing Order*, 1992; Collins, *Gravity's Shadow: The Search for Gravitational Waves*, 2004; Joseph Dumit, *Picturing Personhood*, 2004). These studies built on and critiqued earlier research in the history and sociology of science that had identified functional, normative requisites for scientific communities (**Robert K. Merton**, *The Sociology of Science*, 1979) and the paradigmatic development of scientific theories (**Thomas Samuel Kuhn**, *The Structure of Scientific Revolutions*, 1962). While both Merton and Kuhn had described the structures of normal science, for example dialectical developments among theory, experimentation, and career advancement, STS scholars adopted insights from European **critical theory** to pay particularly close attention to the cumulative consequences of micro-transactions, discursive strategies, and forms of representation, as they produced a particular scientific fact or practice (for example David Kaiser, *Drawing Theories Apart*, 2005). These same perspectives and research methods were also adopted to study technological innovation, engineers, and designers (Hugh Gusterson, *Nuclear Rites*, 1996; Gary Lee Downey, *The Machine in Me: An Anthropologist Sits Among Computer Engineers*, 1998; Stefan Helmreich, *Silicon Second Nature: Culturing Artificial Life in a Digital World*, 1998; Katherine Henderson, *On Line and On Paper*, 1999; Trevor Pinch (with Frank Trocco), *Analog Days: The Invention and Impact of the Moog Synthesizer*, 2002; David Mindell, *Between Human and Machine: Feedback, Control and Computing before Cybernetics*, 2002). These closely observed studies of scientific and engineering practice have led to extensive research on processes of cognition and categorization (G. C. Bowker and S. L. Starr, *Sorting Things Out: Classification and Its Consequences*, 2000). Important work, such as Shapin and Schaffer (1985) showed that the mechanical experiments of Robert Boyle did not satisfy Thomas Hobbes's criteria for philosophical truth, and hence their work is a bridge between the philosophy of science and the sociology of knowledge.

These categories are organizing tools for identifying the variation within science and technology studies more than means for identifying the **information** and analysis within any particular text. Many studies can fit within both families of scholarship, looking at the production of science as well as its distribution, appropriation, and implications for particular groups or classes (for example, Londa Schiebinger, *The Mind Has No Sex? Women in the Origins of Modern Science*, 1989; *Has Feminism Changed Science?* 1999). Steven Epstein, for example, described the ways in which gay rights activists became expert analysts of the existing medical knowledge concerning AIDS when the epidemic first took hold and eventually became co-producers of new knowledge, especially treatment protocols in drug trials (Epstein, *Impure Science: AIDS, Activism, and the Politics of Knowledge*, 1998). The research of Emily Martin and Anne Fausto-Sterling responded to critiques of both the science and pseudo-science of **gender** and reproductive medicine while exploring both the production and appropriation of scientific knowledge (Martin, *Woman in the Body*, 1992; Anne Fausto-Sterling, *Myths of Gender*, 1992; Fausto-Sterling, *Sexing the Body*, 2000). The scholarly work on reproductive medicine and technology, like the work on AIDS (Acquired Immunodeficiency Syndrome), followed upon grass-roots activism that exposed the limitations, and often ideological or biased assumptions, of the then conventional science in these areas. Similarly, Troy Duster has shown how biological research can be inadvertently used to feed racist policies, and how tacit assumptions can feed a research agenda (Duster, *Backdoor to Eugenics*, 1990, 2003). SUSAN SILBEY