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Science and Other Indigenous Knowledge Systems

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KNOWLEDGE SYSTEMS AS ASSEMBLAGES OF LOCAL KNOWLEDGE

Cross-cultural comparisons of knowledge and technology systems were a significant feature of STS studies during the 1960s and 1970s (Finnegan & Horton, 1973; Goody, 1977; Hollis & Lukes, 1982; Horton, 1967; Wilson, 1977)[1] but ceased to be an active site of STS work during the 1980s. This retreat from cross-cultural studies is currently being reversed as fresh insights are gained from the intersections of the social study of science with anthropology, postmodernism, feminism, postcolonialism, literary theory, geography, and environmentalism.[2] The characteristics of this renewed approach to the workings of systems of knowledge in disparate cultural contexts differ somewhat from those of past cross-cultural studies in science, technology, and society.

By and large, past cross-cultural work has taken Western "rationality" and "scientificity" as the bench mark criteria by which other culture's knowledges should be evaluated. So-called traditional knowledge systems of indigenous peoples have frequently been portrayed as closed, pragmatic, utilitarian, value laden, indexical, context dependent, and so on, implying that they cannot have the same authority and credibility as science because their localness restricts them to the social and cultural circumstances of their production. These were accounts of dichotomy where the great divide in knowledge systems coincided with the great divide between societies that are powerful and those that are not. Here was a satisfying explanation of the relation between knowledge and power.

This framework for comparative analysis can now be dissolved with an explicit focus on the local. Recent studies of science as social action[3] have identified local innovation as the implicit basis of scientific knowledge and have explored epistemological, ontological, and methodological consequences of this insight. What has generally remained unnoticed and unexplored in this new direction of science studies is that recognizing the localness of science subsumes many of the previously supposed limitations of other knowledge systems compared with Western science. Though knowledge systems may differ in their epistemologies, methodologies, logics, cognitive structures, or socioeconomic contexts, a characteristic that they all share is localness. Western contemporary technosciences, rather than being taken as definitional of knowledge, rationality, or objectivity, should be treated as varieties of knowledge systems.[4]

In this chapter it is argued that the ways of understanding the natural world that have been produced by different cultures and at different times should be compared as knowledge systems on an equal footing. We range widely across diverse examples of past and present knowledge systems, from the knowledge system within which the builders of Gothic cathedrals worked, to that of past Amer-Indian cultures (Inca and Anasazi), and the still existing Micronesian and Yolngu Aboriginal Australian knowledge systems. In doing so we explore the workings of knowledge systems in ways that can give us more useful understandings of power relations both within knowledge systems and between them.

Bruno Latour (1986) has pointed out that "rationality" is far too mysterious and thin a notion to be useful in accounting for differences between scientific and nonscientific knowledge systems. Instead he proposes many small and unexpected divides that he identifies as located in imaging craftsmanship and technologies of rhetoric. In science, in Latour's account, allies can be better aligned, and can more easily be shown as aligned, than in other systems. The difference between science and other knowledge systems is the result of differences in the effectiveness of technologies of surveillance. Latour has drawn attention to technoscience as a particular tension between the local and the global. Here we draw attention to other knowledge systems

as alternative expressions of the necessary tension between the local and the global, involving different sorts of power practices.

Though scientific culture is now being more frequently recognized as deeply heterogeneous (see, e.g., Law, 1991c; Pickering, 1992b), there is, at present, no term in general usage that adequately captures the amalgam of places, bodies, voices, skills, practices, technical devices, theories, social strategies, and collective work that together constitute technoscientific knowledge/practices. Foucault's epistemes; Kuhn's paradigms; Callon, Law, and Latour's actor networks; Hacking's self-vindicating constellations; Fujimura and Star's standardized packages and boundary objects; and Knorr Cetina's reconfigurations—each embraces some of the range of possible components but none seems sufficiently all-encompassing (Bijker, Hughes, & Pinch, 1987; Callon, Law, & Rip, 1986; Foucault, 1970; Fujimura, 1992a; Kuhn, 1962/1970; Latour, 1987; Knorr Cetina, 1992a). Hence the proposed adoption of Deleuze and Guattari's (1987, p. 90) term *assemblage*, which in their usage is like an episteme with technologies added but that connotes the ad hoc contingency of a collage in its capacity to embrace a wide variety of incompatible components. It also has the virtue of connoting active and evolving practices rather than a passive and static structure. It implies a constructed robustness without a fully interpreted and agreed-upon theoretical framework while capturing the inherently spatial nature of the practices and their relations.

Assemblages constitute connections and contrive equivalences between locales in knowledge systems. In research fields and bodies of technoscientific knowledge/practice, otherwise disparate elements are rendered equivalent, general, and cohesive through processes that have been called "heterogeneous engineering" (see Law, 1987a). Assemblages are also power practices. Understanding them this way picks up on notions of power as strategic and involved with meaning making. Here the relations of power and knowledge are understood as invested in the material, social, and literary practices of discourse and representation, discipline and resistance.

Among the many social strategies that enable the possibility of "connecting up" are processes of standardization and collective work to produce agreements about what counts as an appropriate form of ordering, what counts as evidence, and so on. Technical devices that provide for connections and mobility are also essential. Such devices may be material or conceptual and may include maps, calendars, theories, books, lists, and recursive systems of names, but their common function is to enable otherwise incommensurable and isolated knowledges to move in space and time from the local site and moment of their production to other places and times. In exemplifying the tension between the local and the global, we look at a variety of knowledge systems. The next section briefly considers the knowledge systems of the Gothic cathedral builders, the Anasazi, the Inca, and the Micronesian Pacific navigators. All these are examples of systems that lack many of the elements often deemed essential to science—writing, mathematics, standardized measurement, laws, theory—yet are also systematic and innovative.[5] They differ from science and each other in the kinds of technical devices and social strategies through which local knowledge is mobilized.

The assemblages that we feature in the second section can be understood as "technologies" through which locales in knowledge systems are connected. In the third section we take two types of assemblages that many would consider to embody the universality of science, that is, theories and numbers; we consider work that has revealed these as assemblages of heterogeneous practices. Thus far we have presented assemblages as "entities" within various knowledge systems; here we look "inside" two such entities. Following this we consider work in the contemporary Australian context where contesting knowledge systems—an Aboriginal Australian knowledge system and the Western scientific knowledge system—are being worked together. Here there is mutual interrogation producing reinterpretations of how the systems might be understood with respect to each other. Though fundamentally different in their ontologies and epistemologies, the knowledge systems of Yolngu Aboriginal Australians and Western technoscience can be worked together to expand possibilities for choice by both Aboriginal and non-Aboriginal Australians. In concluding our chapter we briefly consider more general issues of power with respect to knowledge systems.

DISPARATE DEVICES AND STRATEGIES FOR MOVING AND ASSEMBLING LOCAL KNOWLEDGE

Gothic Cathedral Builders

The Gothic cathedrals, and in particular Chartres, have the appearance of the rationality, order, calculation, and uniformity that typify Western science. Our "forms of life" have so structured our understandings of the processes of knowing and making involved in the building of Chartres Cathedral that we take it as self-evidently necessary that such large, complex, innovative structures require an architect and plans. Simultaneously we feel constrained to attribute to its builders some mysterious and ineffable skill because they had no knowledge of structural mechanics.[6] A recent reanalysis of the building of Chartres Cathedral in the eleventh century shows that rather than being a uniform and coherent whole it is an "ad hoc mess" and was achieved

without an architect, without plans, and without a standard measure (James, 1982). It was built in a discontinuous process by successive and different teams of masons using their own "local" geometries, techniques, and measures. The question is then: How was the work of all these people coordinated without the social technologies of planning, calculating, and designing that we take for granted? The answer lies mainly in the use of templates, which are patterns or molds, usually outlined on a thin piece of wood, that a stonemason uses to cut a stone to a particular shape.

The power of templates lies not only in the way in which they facilitate accurate mass production but also in the fact that simple geometrical rules of thumb will often suffice for the templates themselves to be accurately reproduced as often as required. Templates help to make possible the unified organization of large numbers of men with varied training and skill over considerable periods of time.

> On them were encapsulated every design decision that had to be passed down to the men doing the carving in shop and quarry. Through them the work of all the masons on the site was controlled and coordinated. With them dozens, and in some cases hundreds, of men were guided to a common purpose. They were the "primary instruments" of the trade. (James, 1989, p. 2)

In addition to the power to organize large numbers of workers, templates have the power to allow for great exactness of stonecutting and enable the building of a coherent structure, despite a discontinuous process and despite radical design and structural changes. The example of Chartres is especially important in enabling us to rethink the essential elements of a knowledge system. The work of groups of people with varied practices, skills, and understandings has to be rendered connectable and assemblable into a coherent whole whether the outcome is a cathedral, a body of theoretical knowledge, or an agricultural system. The case of Chartres shows that this can be achieved without structural theory, standard measures, plans, or architects; all that is required is a small piece of representational technology in conjunction with skills and constructive geometry. This example undermines some of the great myths about science, technology, and traditional knowledge. There is no great divide between the past and the present, between scientific and traditional knowledge, or between science and technology. Just as "Chartres was the ad hoc accumulation of the work of many men" (James, 1989, p. 2), so technoscience or any knowledge system can be ad hoc, ununified, atheoretical, lack a common measure, and still be effective—fundamentally because all knowledge systems are local and are the product of collective practice based on the earlier work of others.

The Anasazi

The Anasazi were a group of North American Indians who established themselves in what is now the Four Corners region (where Colorado, Utah, New Mexico, and Arizona meet) of the United States from around 200-700 A.D. They not only managed to survive in this most inhospitable region where the temperature ranges from 20°F below to 100°F above and where there is only 9 inches of rain often in destructive summer bursts, but they also created a complex society (Lekson, Windes, Stein, & Judge, 1988, p. 100). This society came to an abrupt end in about 1150 A.D. (possibly due to the drought between 1130 and 1180, though this is debatable). At its peak it consisted of 75 communities spread across 25,000 square miles of the San Juan Basin linked into a socioeconomic and ritual network centered on Chaco Canyon (Judge, 1984, pp. 1-12).[7] On the floor of Chaco Canyon were built massive stone buildings up to four stories high with hundreds of rooms including vast storage areas and huge round underground *kivas,* or temples. Chaco was connected to many of the outlying communities by over 400 kilometers of roads. In addition to the great buildings and the roads, the Anasazi built an enormous irrigation system with check dams, reservoirs, canals up to 50 feet wide, irrigation ditches, and leveled fields with banks (Frazier, 1986, pp. 95 ff.; Vivian, 1974).[8]

The key to supporting a population variously estimated at up to 10,000 in such a marginal environment was the development of an agricultural and storage system that enabled them to grow and redistribute a surplus. But by itself that would not have been enough. To successfully transform an almost totally arid environment, to coordinate the work of large numbers of people over a vast area, and to ensure the growth, storage, and redistribution of food, a large amount of knowledge and information had to be developed, sustained, and transmitted. This was achieved primarily with the calendar along with ritual, myth, poetry, and architecture.

The calendar was maintained by the sun priest's observation of the sun's seasonal passage past markers on the horizon and through the passage of light and shadow in buildings and structures like that on top of Fajada Butte. It was crucial that the solstice be accurately forecast because the timing of the planting calendar is of great moment in an environment with a short growing season and where the onset of frost must be anticipated.

McCluskey (1982) concludes of the contemporary Pueblo astronomy of the Hopi: "Considered as astronomy it shows all the concern with exact observation and the development of observational and theoretical framework that we would expect of modern astronomy" (p. 55; see also McCluskey, 1980).

This too can be said of the Anasazi even though the system was typically local. It strongly reflected its context of use in that it relied on specific horizon markers to record the sun's movements but it was nonetheless capable of movement to different places and times while simultaneously adapting to changing understandings and needs and providing for the growth of an extensive and complex society.[9] The potential for connectivity and equivalence is provided by the directionality that structures the calendar and their social life. All events, places, and people can be recognized, connected, and made equatable through the system of directions represented by the calendar. For its survival and transmission, this system is dependent on annual horizon observations and rituals organized by the sun priest—hence its limitations. The Anasazi knowledge system can move only as far as the priest can control.

The Inca

We turn now to the Inca, whose society and knowledge system has obvious parallels with those of the Anasazi but whose scale and power is very much greater. Indeed, their civilization is usually and quite justifiably referred to as the Incan Empire. At its height the Incan Empire extended over large areas of what is now Ecuador, Peru, and Chile. This organization of 5 million people in one state has been the subject of much speculation and admiration. It has been described as socialism, feudalism, despotism, a hydraulic society. Its coherence has been attributed to the hierarchy, the military, the tax system, laws, bureaucracy, land rights, political jurisdiction (Moore, 1985, pp. 1 ff.). However, we want to argue that, as in the case of the Anasazi, an essential element is the way in which local knowledge was moved and that, as for the Anasazi, the key device was the calendar. Further, the difference in scale and power between the two societies can be explained by the Incan augmentation of knowledge transmission through the use of the additional devices of stone alignments and knotted string, of *ceques* and *quipus.*

The Inca capital, Cuzco, was at the hub of the empire, which stretched over 2,000 kilometers from its most northern extremities to its most southern; but not only was the empire very far flung, it also incorporated a large number of preexisting cultures and covered very variable terrain from the highest parts of the Andes to the coastal plains. The key problem, as for the Anasazi, was how to coordinate a large population in an environment that was at best variable and at worst marginal, and furthermore how to administer it all from one center—Cuzco.

Spreading out from Cuzco were 41 radial lines marking significant rising and setting points on the horizon for the sun, moon, and stars (Zuidema, 1982a). These lines were the *ceques*, marked at intervals by stone cairns or shrines called *huacas.* These ceques not only integrated religious and astronomical knowledge but also provided the basis for the kind of precision calendar required by a state bureaucracy that had to record and correlate information about irrigation, agriculture, trade, warfare, and all the associated taxes, manpower, and resources—all of which operated in a intricate system of kinship, age, class, and social organization. The ceques were extended beyond the horizon to incorporate the whole empire and "formed a system of coordinates by which information of very different orders was organized, as is done in our maps" (Zuidema, 1982b, pp. 59-60), and in fact the Inca created very sophisticated three-dimensional maps of the landscape (de la Vega, 1961, p. 78). In addition to the ceques, the Incas developed a sophisticated system of tallying using knotted strings or *quipus.* On such knotted and looped strings it was possible to record a wide variety of information from instructions to details of taxes, labor obligations, and agricultural supplies, and the quipus could be carried by runners, or *chasquis,* over the extensive road network that ran the entire length of the country in two parallel systems.

Quipus have been extensively analyzed by the Aschers (1972, pp. 288-289; see also Ascher & Ascher, 1981), who conclude that

> To maintain a population that may have reached six million, knowledge of food production is indispensable. And in a land of steep mountains, knowing how to get enough food means discovering the altitudes where particular plants and animals flourish. We must postulate and indeed have evidence for, thousands of years of experimentation and the accumulation of information about plants, animals, and vertical landscapes as they relate to basic human requirements. The native Andeans dug irrigation canals, built bridges, and constructed community store houses. Clearly technical knowledge was needed to do these things, but knowing how to organize and direct large groups of people to do the work and keep the system going must also be postulated.

The orderly provision of knowledge capable of being used to organize and direct large groups was the role of the calendar, the quipu, and the ceques. The quipu and the ceques have a very strong set of similarities and redundancies of the kind that make for a very effective communication system. Zuidema (1977) points out that

> the ceque system has been compared to a giant quipu, laid out over the Cuzco valley and the surrounding hills that served in the local representation of the Incan cosmological system, in its spatial, hierarchical and temporal aspects. . . . Not only can the ceque system be compared metaphorically to quipu but every local group did in fact record its ceque system, that is, its political, religious and calendrical organization on a quipu. (p. 231)

Elsewhere, Zuidema (1982a) argues that

> as projected onto the landscape, the *ceque* system of Cuzco—with all the calendrical rituals carried out in relation to the huacas (places of worship) and ceques mentioned by it—was itself a table, like the *quipu* explaining it. The visibility of all the *ceques* from one centre meant that a person located in the Temple of the Sun had before him "an open book." The *ceques* organized space as a map and made reflection upon it as possible as if the person were seeing an actual map. (pp. 445-446)

The power of the Incan knowledge system lay in its capacity to provide connections for a diverse set of knowledges and to establish equivalences between disparate practices and contexts over a very large area. It was able to do this to a greater extent than the Anasazi's because the quipus and ceques were able to extend the range of their calendar beyond the horizon.

The Incan example also illustrates the failure of Jack Goody's dichotomy between oral and literate societies. Here we have a society that manifested an interest in abstract critical thought, empirical verification, lists, and tables, but without writing. Further, just as Shapin and Schaffer found that the European scientific revolution went hand in glove with the establishment of social order, so Zuidema (1982a) finds: "The Incan interest in exact and systematic knowledge springs not from a pragmatic interest in the measurement of volume or distance but from an interest in 'abstract and moral concepts such as "sin," "secret," "health," "obligation," and "order" ' " (p. 425).

The Pacific Navigators

The knowledge system of the Pacific navigators has much in common with that of the Anasazi and the Incas: It is embedded in an oral culture; it is structured on orientation; and while having large practical and astronomical components, it is an integrated body of natural knowledge. But it differs in some crucial aspects. It enabled the discovery and colonization of totally unknown territory, and its principal device for moving the knowledge is almost entirely abstract with no material manifestation.[10]

The Pacific navigators combined knowledge of sea currents, marine life, weather, winds, and star patterns to form a sophisticated and complex body of natural knowledge. This knowledge system combined with their highly developed technical skills in constructing large seagoing canoes enabled them to transport substantial numbers of people and goods over great distances in extremely hazardous conditions and to establish autonomous communities on distant islands—communities that were nonetheless able to return and maintain their cultural links.

One manifestation of the great divide is the claim that the finding of the islands in the Pacific by these early voyagers was accidental, as opposed to the "deliberate" discovery by the Europeans.[11] The Micronesians, in this account, had only a "traditional" knowledge system inadequate to the complex and difficult task of discovering the unknown; the scientific Europeans, by contrast, were able to plot a course and establish the position of unknown islands and were thus able to bring the knowledge back.

The ability to bring the knowledge back and enable two-way communication is the fundamental prerequisite for a knowledge system to transcend the "merely" local. There is now a good deal of evidence from archaeology, linguistics, anthropology, computer simulation of drifting, and experimental voyaging to show that the Pacific was colonized by one group of people with a complex and common culture. Such cultural integrity could not have been maintained if groups had drifted off, unable to return or communicate.

Thomas Gladwin (1970, p. 34) in his classic work on the Micronesian navigators has highlighted some very important characteristics of their knowledge system. First, their knowledge of the islands and star courses is like a map. In Bateson's (1980) evocative phrase, it is "the pattern that connects" (p. 4; see also Goodenough & Thomas, n.d., p. 15). Second, Gladwin (1970) makes the important observation that navigational knowledge is not an isolated system but is an intimate part of "a network of social, economic and often political ties" (p. 35). But it is not merely practical, "it adds a measure of meaning and value to every act, on land as well as at sea" (p. 35). Navigation is thus a major constituent of the "world of the Micronesians" and their distinctive way of knowing.

The three main practical skills of the Pacific navigator are the ability (a) to determine direction and maintain a course at sea, (b) to keep track of his position by dead reckoning, and (c) to have a system of expanding the island target to augment the chance of successful landfall. The major conceptual device used to determine direction and steer a course is the "star compass." But the star compass alone is not enough. It has to be integrated with the system of dead reckoning called *Etak.* A basic necessity for navigating is the ability to estimate how far you have travelled given the effects of current, drift, wind, and speed. The Micronesian solution is a mental mode of visual representation, of mapping the world in the mind.

On a given voyage between islands, an island to one side of the seaway is chosen as a reference point. These reference islands are part of the sailing directions learned by the apprentice navigator for each island passage. Given that the rising and setting points of the stars are fixed points on the horizon, it is easier for the navigator to mentally represent the actual line of travel of his canoe by breaking it up into conceptual segments. The navigator does this by conceiving his canoe to be stationary and the reference island as moving backward against the backdrop of the rising and setting points of the stars. As the reference island moves from one such point to another, it completes a segment of the voyage.

> *Etak* provides a framework "into which the navigator's knowledge of rate, time, geography and astronomy can be integrated to provide a conveniently expressed and comprehended statement of distance travelled." It is a tool "for bringing together raw information and converting it into the solution of an essential navigational question, "How far away is our destination?" (D. Lewis, 1975, p. 138; see also Hutchins, 1983)

The key point to recognize is that Micronesian navigation is more than a means of dead reckoning. It is a dynamic integrative conceptual framework. It enables the smooth meshing of the two conceptual devices, the star compass and *Etak,* so that the learned body of knowledge of star courses and sea-marks can instantaneously be summoned to the task of processing the observations of the moment. The total system forms a "logical construct or cognitive map" (Gladwin, 1970, p. 181).

The third, essentially strategic, element of the system is the technique of "expanding the target." Low islands can be easily missed so the target is expanded by looking for patterns of ocean swells, flights of birds, cloud formations, and reflections on the undersides of clouds. The islands are also in chains as a result of their formation at the edge of crustal plates, so the navigator can orient himself by intersecting the chain at any point.

Gladwin (1970) says that Puluwat navigation is "entirely a dead reckoning system" and "depends upon the features of sea and sky which are characteristic of the locality in which it is used" (p. 144). By "local," Gladwin means not only that the system depends on using knowledge and observations specific to the area but also that the techniques employed are specific to the individual island community. In the Marshall Islands, for example, they use wave interference patterns to maintain direction whereas the Puluwatans do not. In one reading this would seem to severely constrain the kind of knowledge deployed by the Micronesian navigators. However, while it is true that it uses dead reckoning, as we have already seen, it is not *merely* a dead reckoning system because at its core lies a dynamic cognitive map. It is this characteristic that enables it to move beyond the local. Much of our Western misunderstandings of how this can be may result from the embeddedness of the concept of plan. Just as the cathedrals could be built without one, so too can the navigators operate successfully in an ad hoc and planless way.

Lucy Suchman (1987) argues that

> in Micronesian navigation nowhere is there a preconceived plan in evidence. The basis for navigation seems to be instead, local interactions with the environment. The Micronesian example demonstrates how the nature of an activity can be missed unless one views purposeful action as an interaction between a representation and the particular contingent details of the environment. (p. 187)

Thus she concludes that

> the function of abstract representations is not to serve as specifications for the local interactions, but rather to orient or position us in a way that will allow us, through local interactions to exploit some contingencies of our environment and avoid others. (p. 188)

There are three major problems involved in the learning and use of a complex body of oral knowledge like that of Micronesian navigation. The first is the development of techniques to ensure that the vast body of detailed data is accurately retained and passed on over generations. The second is that the body of data must be instantly accessible to the user. It would be of no assistance to the navigator if he had to work through lists of items to get the desired bit. He must be able to instantly access any part of the system. The third is that the system must of necessity be local in nature but it must also be capable of moving beyond the local into the unknown. The first problem is resolved in part by a variety of strategies: the encoding of knowledge in songs and ritual, group learning and testing sessions, mnemonics, overlapping and redundant ways of connecting the knowledge, and constructing material models of the system, like the stick charts and stone arrangements (Farrall, 1981; Goodenough & Thomas, n.d.). The second problem is of course largely resolved through constant repetition and practice until the knowledge becomes completely tacit—an unreflective skill. But one of the most important components of this tacit knowledge or skill is the navigator's constant awareness of where he is on or, more precisely, in his cognitive map. It is that cognitive map that simultaneously provides a basis for solving the first two problems by providing the possibility of creating connections and equivalences and that also enables the knowledge to move.

The template of the Gothic cathedral builders, the calendar of the Anasazi, the calendar of the Incan empire in association with the working of ceques and quipus, and the complex cognitive "technology" of the Micronesian navigators of the Pacific—all are examples of the melding of quite heterogeneous and disparate practices to form stable assemblages that connect. Though quite disparate in their makeup, they can all be understood as giving impetus to the systemic aspects of knowledges. Thus they are "technologies" carrying the "power of the center," disciplining life at the local level in constituting a knowledge system. As quite different sorts of "technologies," they articulate systems in quite different ways. The micropower practices engaged in are qualitatively different; different degrees of "negotiation" between the local and the global are enabled through the "technologies."

THEORIES AND NUMBERS AS HETEROGENEOUS ASSEMBLAGES

So far we have described the working of various types of connecting assemblages as "entities" within disparate knowledge systems; now we look "inside" two such entities that can be understood as connecting locales of work in science. In this section we take two types of heterogeneous assemblages that many would consider to embody the universality of science—theories and numbers. We consider work that has revealed these as "technologies" enabling systematizing in science. Engaging Star's (1989a) treatment of theories in science as connecting assemblages that are both plastic and coherent, we take up an argument that one of us has previously made showing numbers as similarly heterogeneous (H. Watson, 1990).

Emphasizing the local in science necessitates a reevaluation of the role of theory. Typically philosophers and physicists have theory as providing the main dynamic and rationale of science as well as being the source of its universality. Karl Popper, for example, claims that all science is cosmology and Gerald Holton sees physics as a quest for the "Holy Grail," which is no less than the "mastery of the whole world of experience, by subsuming it under one unified theoretical structure."[12] It is this claim to be able to produce mimetic totalizing theory that Western culture has used simultaneously to promote and reinforce its own stability and to justify the dispossession of other peoples (Graham, 1991, p. 126). It constitutes part of the ideological justification of scientific objectivity—the "god-trick" as Haraway (1991a, p. 189; Nagel, 1986) calls it—the illusion that there can be a positionless vision of everything. The allegiance to mimesis has been severely undermined by analysts such as Rorty but theory has also been found wanting at the level of practice, where analytical and empirical studies have shown that it cannot and does not guide experimental research (Cartwright, 1983; Charlesworth, Farrall, Stokes, & Turnbull, 1989; Rorty, 1979). The conception of grand unified theories guiding research is also incompatible with what Leigh Star has pointed to as a key finding in the sociology of science: "Consensus is not necessary for cooperation nor for the successful conduct of work" (Star & Griesmer, 1989, p. 388).[13] In Star's (1988) view,

> Scientific theory building is deeply heterogeneous: different viewpoints are constantly being adduced and reconciled. . . . Each actor, site, or node of a scientific community has a viewpoint, a partial truth consisting of local beliefs, local practices, local constants, and resources, none of which are fully verifiable across all sites. The aggregation of all viewpoints is the source of the robustness of science. (p. 46)

> Any scientific theory can be described in two ways: the set of actions that meet those local contingencies . . . or the set of actions that preserves continuity of information in spite of local contingencies. These are the joint problems of plasticity and coherence, both of which are required for theories to be robust. Plasticity here means the ability of the theory to adapt to different local circumstances to meet the heterogeneity of the local requirements of the system. Coherence means the capacity of the theory to incorporate many local circumstances and still retain a recognizable identity. (p. 21)

Theories from this perspective have the characteristics of what Star (1989a) calls "boundary objects," that is, they are "objects which are both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites" (p. 21). Thus theorizing is itself assemblage of heterogeneous local practices.

Star's treatment of theory as standardizing practice is worked out in her study of scientific work, which led to the development of the theory of physical localization of brain function. Star presents us with a picture of a theory growing from particular situations and "clotting" to become a form of standardized knowledge. As we see the theory "clot," we see values inherent in the work activities of the collective become encoded in the cohering yet heterogeneous form or assemblage that their work produces. The theory is as much prescriptive of practical action as it is an explanation of brain function; it demands belief and commitment to the values it encodes.

Theories as assemblages are the end result of many kinds of action, all involving work: approaches, strategies, technologies, and conventions. The component parts of a theory become increasingly inseparable as it develops; they become thicker or more clotted; events, observations, and assumptions come to be seen as connected. The most successful (i.e., the most robust) theories become so clotted, so multirooted, that they are in Latour's terms "black boxes," obligatory passage points in vastly different enterprises. In making this point at the beginning of *Science in Action*, Latour (1987) juxtaposes the theory of DNA structure in 1956 with the routine black box that people work through as the transparent technology that the theory had become by 1987.

While the term *black box* emphasizes the coherence of these forms, as a metaphor it does not adequately evoke the plasticity of these robust forms.

Black box implies design and fails to convey the notion that standardized forms of knowledge are the coagulated consequence of the work of a collective, where diverse interests expressed in a common situation are bound into the robust form enhancing (paradoxically) both its plasticity and its coherence. Failing to recognize the plasticity that goes along with the integrity and coherence of black boxes, Latour (1983), and likewise Rouse (1987), have standardized forms of knowledge swarming unimpeded out of the laboratory. As they see it, resistance is useless.

The robustness in theories with contradictory elements of flexibility and coherence, which we see through work like Star's, is important. It enables us to recognize the continuities between the relatively "freshly" assembled knowledge forms of our time, like the theory of DNA or the theory of physical localization of brain function, and other more pervasive and well-established standardized forms such as number and quantification, which are implicated in so much of Western life, particularly science.

Just as the theory of the physical localization of brain function has been revealed as a social product, so too have number and quantification (H. Watson, 1990). Quantification is a surprising weaving together of practices of ordinary talk and material practices. We can see this when we juxtapose "natural number" in two radically different language communities, for example, the Yoruba community of West Africa and the English-speaking community. Three quite different sets of practices are "clotted" together in both Yoruba and Western quantification.

One set of practices concerns the categories that language users adopt through engaging the particular method of predication in the language—a historical "accident." This set of practices has the speakers of a language constituting the universe with particular kinds of entities. The way we predicate and thus come to talk of "things" in English has us talking of entities individuated in space and enduring as such across time—entities in a spatiotemporal sense. The analogous set of practices in Yoruba has speakers talking of entities constituted on the basis of what in English we understand as qualitative properties, for example, the "waterness of water." A Yoruba language answer to the question, "What is it?—"*Kí nì yí?*" to which an English speaker replies, "It's water," could be "*Omi ni ó jẹ́* " (literally translated as "Watermatter [matter with the characteristics of waterness] here manifests its inner intrinsic and permanent nature"). We see that Yoruba *omi* is quite a different sort of category than English *water.*

These disparate categorizing practices that form part of ordinary language use are tied up with differences in what we would normally consider to be the practices of quantifying. In English language we understand qualities of spatiotemporal entities as constituting the basis of "unitizing" the material world prior to quantifying. If spatiotemporal entities have numerosity, then that is the quality we use, and we say we "count." With spatiotemporal entities that cannot be understood as having the property of numerosity, other qualities (length, mass, and so on) can be used to constitute temporary units understood as analogous to things, and we measure. For Yoruba speakers, with a world already categorized on what English speakers understand as a qualitative basis, the modes in which these sortal particulars manifest, with varying degrees of dividedness, constitute the basis of quantification. The sets of unitizing material practices incorporated into *kà* and *wọ̀n* might resemble the sets of unitizing practices built into counting and measuring, but because the categories taken to constitute the world differ, the sets of practices hold together in different ways.

Constituting a recursion of names is the third set of practices that contribute to the assemblage of "natural number." The role of fingers and toes in both the Western and the Yoruba assemblages is implicit. In both cases seriation in words is patterned on the scale of finger-toes, but there are significant differences. The contemporary numeral recursion that has developed with English has ten as its base—"ten" is the point in the series of words that marks the end of the basic set. As each ten is reached, the basic series is started again in a systematically modified form. The rule by which the series continues is addition of single units. Yoruba numerals are a multibase recursion. The most important base is twenty (*ogún*). Ten (*èwà*) and five (*àrùún*) provide points at which the twenties are broken up. The rules for working the recursion make little use of addition; the processes of multiplication and subtraction are more important. We can explain the difference between English and Yoruba in the practices of numeral recursion by going back to the primary categories in the language. When the entities talked of are spatiotemporal objects, the linguistic code explicitly differentiates fingers from one another. When the primary entities talked of are sortal particulars, a linguistic code to report the position on the finger-toe scale must necessarily be more complex. With the primary categorical distinction of Yoruba, the fact that finger-toe matter ordinarily manifests in sets of twenty with inherent divisions into collections of ten and five is relevant—a sortal particular—and a person coincides with the manifestation of finger-toe matter in this way.

Thus a cross-cultural tension enables us to see number and quantification as the "clotted assemblage" of three quite heterogeneous sets of practices: linguistic practices of designating, material practices of unitizing matter, and practices of tallying units through linguistic analogy to fingers and toes. In the past, in communities speaking Indo-European languages and in those speaking West African languages, number and quantification have resulted from efforts of people to produce meaning. But this has been forgotten as we

just go on using number as a standardized form of knowledge that has become so "clotted" as to now be considered part of our grammar.

We can extend the insights Star has given us into the development of theories as clotted assemblages that connect locales of work, to understand quantification as just another robust, clotted form of knowledge that originated in particular situations and enterprises. Par excellence, it displays both plasticity and coherence. Through number, other accomplishments are possible; it is "a technology." Understanding number as contrived in past work by people is likely to be a rather startling idea for some, yet it is a useful way to understand number as a social phenomenon. It is an understanding that has been crucial for the work we describe in the next section.

WORKING WHERE KNOWLEDGE SYSTEMS OVERLAP

This section describes work that is situated both within social science and within the Yolngu Aboriginal Australian community that holds lands in the northeastern section of the Northern Territory of Australia; it is work within the historically layered contestation between white Australia and Aboriginal Australia.[14] The Yolngu Aboriginal system of knowledge claiming reach over Yolngu lands understands itself as coherent and exhaustive; while seeing itself as a distinct entity, it does not assert incommensurability. Contemporary Aboriginal knowledge systems are less powerful than the contemporary scientific knowledge system; they survive in centers remote from the centers of scientific knowledge.

We can conceive of a knowledge production endeavor simultaneously located in dual contesting systems; boundaries between knowledge systems are vague and indefinable. Knowledge systems are polysemous so that where one system leaves off and another starts is a matter for strategic negotiation on the part of those involved in knowledge production enterprises. Locating across cultural traditions can render visible the strategies and technologies (i.e., the power practices) embodied in each of the systems. The research program described here involves practical mutual translation achieved through mutual interrogation. Part of the work is to display the standardized assemblages of heterogeneous practices of each knowledge system to the other, all the while resisting the production of new knowledge in both systems.

The work does not romanticize and/or appropriate the vision of the less powerful Yolngu knowledge system. The contemporary Aboriginal Australian systems of knowledge are no more innocent than contemporary scientific knowledge, yet they are a useful counterweight because, as subjugated knowledges, they are less likely to deny the critical and interpretive core of all knowledge.

> They are savvy to modes of denial through repression, forgetting and disappearing acts—ways of being nowhere while claiming to see comprehensively. The subjugated have a decent chance to be on to the god-trick and all its dazzling—and, therefore, blinding—illuminations. (Haraway, 1991a, p. 191)

The possibility of dual system knowledge production and the terms within which it might be accomplished are contested both within science-based Australian culture and within Yolngu culture, and in both argument is needed. But cogent argument is not the only aspect of the work. This is an endeavor of practical politics. What we are producing—practical criticism of past ways of understanding ourselves, and relations between the two peoples, and reinterpretation of the political and social processes of those relations—is of course subject to standards of theoretical coherence and empirical adequacy. But its overall adequacy is not determined solely by such criteria. The constructions that we are generating are "verified" also by participants engaging with the newly apparent sets of possibilities for social action.[15]

In contemporary Australian life, there are areas of continuing political contestation between Aboriginal and European traditions. In these places interaction between the knowledge production systems is still hot and controversial after 200 years of mutual involvement. Education of Aboriginal children is one such area; another concerns land ownership and usage. In the past, controversies in these areas have been closed by adjudication on the issues by non-Aboriginal authorities who have taken the view that there is only one legitimate knowledge system and that, insofar as claims are made from within other systems, these are taken as both illegitimate and inferior. Our research attempts to go beyond confronting adjudication. At present the research is focused on the generation of an education appropriate for Yolngu children. A particular emphasis within this is the mathematics curriculum.

The concerted use of three stabilized sets of practices in the Yolngu Aboriginal Australian community makes it possible for people and places to be joined in a formally related yet dynamic whole. These are analogous to the three sets of practices that we can understand as constituting quantification. All Australian Aboriginal peoples use a formalized recursive representation of kinship as the major integrative standardized form in much the same way that the formalized recursion of tallying—number—constitutes an integrative standardized form of knowledge in Western societies. The Yolngu Aboriginal Australians know their system as *gurruṯu,* which is an infinite recursion of a base set of names patterned on family relations enabling everything to be named and related and imposing an order on the entire world.

Gurruṯu is a recursion of names that are understood as names of qualitatively different relations (or at least that is how we can characterize it in English), not as names of varying extents or degrees within a particular qualitative relation—hierarchy—as number is. This difference is associated with a profound difference in the primary categories of Yolngu language compared with English. As we have already noted, English has its speakers designating entities in the sense of spatiotemporal entities. In contrast, Yolngu language has speakers designating relations between connoted entities.

To understand this distinction better, imagine a photograph of some canoes drawn up on a beach. Asked to describe the photograph, an English speaker might say, "Canoes are lying on a beach." A Yolngu speaker might say, "*Rangi-ngura nyeka lipalipa.*" A close English translation of this statement would be something like "Beach-on staying canoe." Considering these further we can see that the English *canoes* countenances spatially separated units that can manifest in collections of one or more. In the Yolngu language statement, the types of elements in the scene are *rangi* (beach) and *lipalipa* (canoe) type elements. The suffix *-ngura* is one of many suffixes in Yolngu language that, when joined to another term, like *rangi,* names the relation between the elements in the scene. What is being talked about here is a relation—"beach-on" —between different types of elements. We can understand "beach-on-ness" or "beach-at-ness" as the subject of the sentence. The term *nyeka* implies "sitting at or staying at a place"; it tells us something about the *-ngura* (the "on-ness" or "at-ness").

Just as we saw the type of designating category having consequences for the type of recursion engaged in Yoruba quantification, we see that in the Aboriginal Australian Yolngu language talking of relations is associated with a recursive pattern of names of relations deriving from the material pattern of family relations. Thus we see how two of the disparate sets of practices hang together.

The third set of practices that helps constitute the working assemblage has to do with mapping the land and associating particular sections of *gurruṯu* with particular places. This involves sets of material practices associated through idealized narratives of journeys made by idealized ancestors that relate particular places to contemporary Yolngu people. In much the same way sets of material practices are associated through "stories" of qualities inherent in spatiotemporal entities that enable the "application" of the number recursion to the material world. For Yolngu the travels and activities of the ancestors in creating the landscape constitute tracks or "songlines"—*djalkiri*—that traverse the whole country (see Watson, with the Yolngu, & Chambers, 1989, for a more detailed description of these two sets of practices). The use of *gurruṯu* and *djalkiri* together accomplishes the same sorts of ends that the use of number and quantification accomplishes in the West.

Number-quantification juxtaposed with *gurrutu-djalkiri* focuses them both up as contrived systematizing "technologies" formed by and in turn shaping Western life and Yolngu Aboriginal life, respectively. Both normally remain invisible, their historicity stripped away; they have been naturalized to become part of the grammar of these forms of life. Judgments and choices, both individual and collective, are made through number-quantification and *gurrutu-djalkiri*, but as "technologies" they presuppose particular and qualitatively different distributions of power and open up possibilities for choice and judgment in different ways. And this can only be seen when their "naturalism" is stripped away through juxtaposition. For Aboriginal Australia, *gurrutu*—engaging the ties of kinship—is reestablished as a valid "technology" through which community and individual decisions can be rationally made and through which contemporary Yolngu community life is enhanced and extended. At the same time a "technology" of social order en- coding a set of values opposed to the rationality of numbers can be effectively revealed in the wider Australian community.

The possibility of reframing Yolngu concepts within Western knowledge and vice versa through the plasticity of number-quantification and *gurrutu-djalkiri* requires each side to assimilate something of the other. In this process Yolngu look for and emphasize metaphor in Western knowledge. Science looks for and emphasizes codification and develops a grid in which two systems can be seen in ratio. On the Yolngu side two metaphors have been developed as the framework to carry the practices of translation. They originate in the natural process of the Yolngu lands. On other hand, *Balanda*[16] researchers couch their framework in terms of metaphors of construction.

In science, "nature" and "society" are taken as quite different than each other and different than "knowledge"; scientific knowledge sees itself and all other knowledge systems as a representation of reality. What is taken as important in scientific knowledge is adjudication over true and good representations. This is in stark contrast to Yolngu knowledge, which is strongly antirepresentationalist and does not see nature-society-knowledge as constituted of distinct and different sorts of things. We might characterize Yolngu knowledge as idealist, as distinct from empiricist science, so that the forms of evidence considered relevant for Yolngu knowledge claims differ from those considered relevant in science. This goes along with recognition and reverence for the context of production of knowledge claims so that Yolngu knowledge celebrates itself as highly indexical (see Watson et al., 1989, p. 30).

The process of mutual interrogation and the negotiated making available of knowledge of one world in another is familiar practice for Yolngu. For their world has two mutually exclusive components: the *Dhuwa* and the *Yirritja*. These fundamental categories of Yolngu life are constituted by people and places, flora and fauna, words and songs, stories and metaphors,

dances and graphic symbols. Everything, every person, every concept, every place that matters in the Yolngu world is either Yirritja or Dhuwa. Dhuwa *rom*[17] is made available to Yirritja clans for their use and vice versa; there are accepted ways of presenting Yirritja in the Dhuwa world and the Dhuwa in the Yirritja. Explicit acknowledgment of the process of mediation through use of metaphor is commonplace in the Yolngu world.

The metaphor through which the work proceeds on the Yirritja side of the Yolngu world, *ganma*, is the dialectic of the meeting and continual mutual engulfing of two rivers. The rivers have different sources and as they flow into each other their separate linear forces acquire the force of a vortex. This vortical flow gives deeper penetration into understanding and knowledge. In terms of the research project, the *ganma* metaphor is taken as the dialectic of a river flowing in from the sea (Western knowledge) and a river flowing from the land (Yolngu knowledge) continually engulfing and reengulfing each other as they flow into a common lagoon. In coming together the streams of water mix across the interface of the two currents and foam is created at the surface so that the process of *ganma* is marked by lines of foam indicating the interface of the two currents. In the terms of the metaphor, this text is part of the line of foam that marks the interface between the current of Yolngu life and the current of Western life.

On the Dhuwa side the research work proceeds through the *Milngurr* metaphor. This sees the dynamic interaction of knowledge traditions as the interaction of fresh water from the land bubbling up in fresh water springs to make water holes, and salt water moving to fill the holes under the influence of the tides. Salt water from the sea and fresh water from the land are eternally balancing and rebalancing each other. When the tide is high, the salt water rises to its full. When the tide goes out, fresh water begins to occupy the water hole. *Milngurr* is dual and balanced ebb and flow. In this way the Dhuwa and Yirritja sides of Yolngu life work together. And in this way Balanda and Yolngu traditions can work together.

Over the past few years negotiations have been conducted among Yolngu people (and are still continuing) about the use of these metaphors to underpin the enterprise of knowledge production involving both Yolngu and Western forms. For Yolngu this move is a highly contentious issue, because all metaphors are owned by particular clans and encode the interests of particular groups. In turning the metaphors to use in reframing the Western and Yolngu world in each other, we have elaborated the metaphors so that their life is not restricted to the Yolngu polity, yet particular Yolngu people still lay claim to them.

Those of us justifying the claims we are producing within the scientific knowledge production system are also using metaphors, although specific acknowledgment that we are dealing in metaphor within this discourse is not usual. Building and constructive/deconstructive metaphors have been used all through this chapter, which is itself within social science. Much of the deconstructive/constructive work involved in presenting evidence here lies in making analogies. Strict symmetry is essential; neither side is privileged in terms of producing true or good knowledge. We can give an account of the workings of both the scientific and the Yolngu knowledge production systems, showing that in each there are analogous processes of interrogation through which claims are generated, and analogous sets of stabilized standardizing practices through which claims can be mobilized.

Having learned how to see these analogies and understand things in new ways, we are answerable for what we do next. If we are to hope for transformations of systems of knowledge, for the construction of worlds less organized by axes of domination, we cannot present our claims to new knowledge as universal claims. Nor can we treat their mobilization in the dual knowledge production systems within which we work as unproblematic, using stabilized assemblages as though they were transparent technologies. In working through the dual sets of devices and strategies whereby claims are mobilized from Yirrkala, the site of our work, we must "focus up" the forms of association, the values, and the politics embodied in the products and the processes of our work.

We are generating an exemplar. We regard the principles and the processes of our work as generalizable, but the "facts" we produce, with assumptions, values, and ideology built in, should be treated with suspicion. Along with the explanations and practices we are producing that demand belief and that prescribe, we are attempting to make evident, and not transparent, the technologies we are using. The resistance inherent in our endeavor is shown and in turn invites informed resistance to our work.

We are engaged in the production of local knowledge but we are making its situatedness and its mobilization problematic so that the processes are recognizable. Others may consider and adopt our arrangements and understandings for their own purposes, but we are not attempting to enroll them as unwitting allies in our endeavor.

CONCLUSION

Throughout this chapter we have argued for the fundamental importance of the local while recognizing that, as far as knowledge is concerned, localness has paradoxical implications of systematicity. We cannot abandon the strength of standards, generalizations, theories, and other assemblages of practices with their capacity for making connections and at the same time providing for the possibility of systematic criticism. We need to recognize

that "systemic discipline" and "local resistance" are two sides of the same coin; promoting systematicity is a local practice, and local resistance contains the impetus for systematization. If we do not recognize this joint dialectic of the local and the global, we will not be able to understand and hence establish conditions conducive to the possibility of directing the circulation and structure of power in knowledge systems, conditions for promoting redistributions.

Through recognizing the local-global tension of knowledge systems, we have considered the ways in which the movement of local knowledge is accomplished in different knowledge systems, and the consequent effects on the ways in which people and objects are constituted and linked together, that is, their effect on distributions of power. The challenging of the totalizing discourses of science by another knowledge system that we elaborated in the fourth section is what Foucault (1980, pp. 71 ff.) had in mind when he claimed that we are "witnessing an *insurrection of subjugated knowledges*." It corresponds to Clifford Geertz's (1973b) critique within anthropology that cultural meanings cannot be understood at the general level because they result from complex organizations of signs in a particular local context and that the way to reveal the structures of power attached to the global discourse is to set the local knowledge in contrast with it. Where knowledge systems abut and overlap are sites of cultural contradictions. These are local sites where collective resistance on the part of the marginalized is feasible. Such resistance is a challenge over distributions of power and can lead to increased freedoms; more and different choices over how we might live become possible.

The pervasive recognition, characterized as postcolonialism, that the West has structured the intellectual agenda and has hidden its own presuppositions from view through the construction of the "other" (see Clifford, 1988; Diamond, 1974; Nandy, 1988; Said, 1978) is nowhere more acute than in the assumption of "science" as a foil against which all other knowledge should be contrasted. Marcus and Fischer (1986) take this to be a general movement in the intellectual agenda; according to them we are at an "experimental moment" where totalizing styles of knowledge have been suspended "in favour of a close consideration of such issues as contextuality, the meaning of social life to those who enact it and the explanation of exceptions and indeterminants" (p. 8). In this emphasis on the local we are "postparadigm."

However, we should not be too easily seduced by the apparently liberatory effects of celebrating the local because it is all too easy to allow the local to become a "new kind of globalizing imperative" (Hayles, 1990, pp. 213-214). For all knowledge systems to have a voice and to allow for the possibility of intercultural comparison and critique, we have to be able to maintain the local and the global in dialectical opposition to one another (Said, 1990). This dilemma is the most profound difficulty facing liberal democracies now that they have lost the convenient foil of communism and the world has Balkanized into special interest groups, whether of genders, races, nationalities, minorities, or whatever. By moving into comparatist mode, there is a grave danger of the subsumption of the other into the hegemony of Western rationality, but, conversely, unbridled cultural relativism can only lead to the proliferation of ghettos and dogmatic nationalisms (see Adam & Tiffin, 1991, p. xi).

Analysis and critique of scientific knowledge, whether from the point of view of contesting knowledge systems, or any other, is part of science. In carrying out our endeavors, we are obliged to ask: What sort of politics do we want to characterize our knowledge systems? Part of the reason that it is important to identify the established assemblages of practices through which a knowledge system works is to be in a position to infer the forms of association and hence power relations they engender to make it possible to look for ways of remaking them.

The strength of social studies of science is its claim to show that what we accept as science and technology could be other than it is; its great weakness is the general failure to grasp the political nature of the enterprise and to work toward change. With some exceptions it has had a quietist tendency to adopt the neutral analyst's stance that it devotes so much time to criticizing in scientists. One way of capitalizing on the strength of social studies of science, and of avoiding the reflexive dilemma, is to devise ways in which alternative knowledge systems can be made to interrogate each other.

NOTES

1. For a discourse parallel to and more positivistic than the STS work, see the "ethnoscience project": Blaut (1979), Berlin and Kay (1969), Conklin (1964), Frake (1962), and Sturtevant (1964).

2. The renewed focus of interest in cross-cultural studies is indicated by the number of recent conferences featuring cross-cultural approaches: Comparative Scientific Traditions Conference, "Understanding the Natural World: Science Cross-Culturally Considered," held in Amherst, Massachusetts in 1991; the inclusion of two panels, "Ethnoscience" and "Non-Western Approaches to Science and Technology," in the 4S/EASST Conference, Gothenburg, August 1992; Science of the Pacific Peoples Conference, Fiji, June 1992; and Comparative Science and Culture Conference, Amherst, June 1992. For examples of the other intersections, see Krupat (1992), Haraway (1991a), Adam and Tiflin (1991), Said (1978), Clifford (1988), Hayles (1990), Marcus and Fischer (1986), Raven, Tijssen, and de Wolf (1992), Shiva (1989).

3. This has developed in rather different ways in various centers, as we would expect. In Britain the sociology of scientific knowledge (SSK) began the move; translation theory in France and symbolic interactionism in North America have different ways of posing similar puzzles.

4. The term *technosciences* is used to indicate the lack of a fundamental epistemological difference between science and technology as well as their strong interaction in the later part of the twentieth century. The plural is used because there are no homogeneous entities "science" or "technology"; there are instead dynamically interacting sets of heterogeneous practices. On technoscience, see Latour, 1987. On heterogeneous practices, see Pickering, 1992b, for examples.

5. Similar systems of knowledge can be brought to light in a wide variety of cultures that have developed ways of organizing natural knowledge in conjunction with agriculture, irrigation, navigation, hunting, astronomy, and so on. For example, Inuit, Maya, Balinese, Indonesian megalith builders and many African cultures all have such contrived assemblages.

6. The following discussion of Gothic cathedrals is taken from Turnbull (1993).

7. According to the archaeologist Dwight Drager, the road system is linked with signal towers as part of a "vast communication network" (cited in Frazier, 1986, p. 125).

8. The most recent and comprehensive account of the "Chaco Phenomena" is Gabriel (1991; see also Crown & Judge, 1991).

9. There is some evidence for the North American Indian recording of accurate, complex, and detailed lunar and solar calendars in a mobile form as message sticks (see Marshack, 1989).

10. The following account is taken from Turnbull (1991).

11. "All the distant ocean islands in the world must have been discovered in the first place by accident, and not by deliberate navigation to those islands. Navigation implies that the existence and location of one's objective is known, and a course set for it. . . . Unless and until the objective has been discovered, navigation is not an issue. . . . [I]n the case of New Zealand, Hawaii and the other detached Polynesian islands, the prehistoric discoverers had no way of gaining the knowledge necessary for navigation back to their home islands. It will follow that the settlement of these detached islands was contemporaneous with their discovery" (Sharp, 1963, p. 33).

12. Allport (1991), a nuclear physicist, finds solace in Popper and Holton as he bemoans the appointment of Nancy Cartwright to Popper's old position at LSE.

13. Compare with the following: "Scientists can agree in their identification of a paradigm without agreeing on or even attempting to produce, a full interpretation or rationalisation of it. Lack of a standard interpretation or of an agreed reduction to rules will not prevent a paradigm from guiding research" (Kuhn, 1962/1970, p. 44).

14. This section is devoted to the work of Helen Watson-Verran with a group of Yolngu Aboriginal researchers. This research community, which calls itself an action group, was established in 1986. The most enduring products of the work of this group so far are the power to control the education of Yolngu children and also a fundamentally reformulated mathematics curriculum. The most accessible text produced by the group is Helen Watson with the Yolngu Community at Yirrkala and Chambers (1989).

15. We need also to produce demonstrable institutional change—to change the social conditions under which contemporary Australian life (Yolngu and non-Yolngu) is possible in terms of both individual experience and community development.

16. The term *Balanda* is a Yolngu term for non-Aboriginal Australian. It predates the British invasion of the continent and derives from the Macassan word *Hollander.* This word is borrowed from the Macassan traders with whom Yolngu had substantial dealings until the beginning of this century, when the White Australia Policy put a stop to such trading.

17. The Yolngu word *rom* is being used here to imply the extension of the category named by Dhuwa; other translations for *rom* are "the law" or "the logic and reasoning" of Dhuwa clans.