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Introduction

Academic interest in indigenous (or "local") knowledge has grown in recent years, particularly for those interested in grassroots development and natural resource and wilderness management (Menzies 2006; Menzies and Butler 2006; Mistry and Berardi 2016; Ratner and Holen 2007). Based upon work by Harold Conklin (1961), Charles Frake (1962), William Sturtevant (1964), and Brent Berlin (Berlin 1973, 1992; Berlin et al. 1966, 1968; Berlin and Kay 1969), anthropologists have looked to indigenous knowledge, not just as a way of affirming the deep experience that indigenous peoples develop in their own environmental context, but also as a way to explore ways to identify and encourage sustainability in an environment with pressures of population, acculturation, and dwindling resources (e.g., Brondizio and Le Tourneau 2016; Lauer and Aswani 2009; Ratner and Holen 2007; Sillitoe 1998). Most of these studies have focused on subsistence and agriculture (e.g., Benz et al. 2007; Berlin, Breedlove, and Raven 1974; Faust 1998; Ford 2008; Ford and Nigh 2009; Johnson 1974; Lauer and Aswani 2009), crops such as potatoes (Brush 1980; La Barre 1947), maize (Benz et al. 2007; Butler and Arnold 1977), manioc (Kensinger et al. 1975, 43–51), plants (Berlin et al. 1974), ethnomedicine (Ortiz de Montellano 1975), medicinal plants (Caamal-Fuentes et al. 2011; Hirschhorn 1981, 1982), nutritious wild plants (Felger and Moser 1973), fish (Begossi et al. 2008; Chimello de Oliveira et al. 2012), and insects (Oltrogge 1977). Indigenous knowledge also provides a close-up of intimate knowledge of subsistence practices in hostile climates such as the Arctic and perceptions of climate change (Couzin 2007).

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To my knowledge, however, little attention, if any, has been devoted to the study of the indigenous knowledge of crafts and the way in which potters, in particular, perceive and engage their material world in the process of making pottery. Even though my own foray into this world (ethnomineralogy) was published more than four decades ago (Arnold 1971), no book-length study of the indigenous knowledge of crafts, and that of potters, in particular, exists.

Anthropologists and development specialists, however, are concerned with craft production in cultural, environmental, and economic contexts in which agriculture is not possible or is insufficient for survival (e.g., Goff 1990). Indeed, government intervention for developing pottery production in Ticul, Yucatán, in the past tended to ignore local knowledge (both overt and covert) that resulted in repeated failures after investing thousands, if not millions, of pesos (Arnold 2008, 238–39, 245–46; 2015a, 201–12). Such failures are not uncommon in the Third World, and the tendency is to believe that scientific knowledge is superior to local knowledge (described in López Varela 2014) and that natives are ignorant, incapable of learning, or resistant to change. Such prejudicial attributions are, of course, not true because indigenous populations are not ignorant, nor do they resist learning new practices. Native peoples have sustained themselves for hundreds and hundreds of years using their traditional knowledge, and they have adapted to changing circumstances throughout the past (see Killion 1999). This traditional knowledge, however, may be incompatible with top-down development projects that fail to take it into account, fail to respect the local people, and do not understand or appreciate the indigenous perspective (e.g., López Varela 2014; Sillitoe 1998).

Indigenous knowledge is also critical to the study of the historic and prehistoric past. A recent review of an exhibition at the British Library in London documenting the search for the Northwest Passage in the nineteenth century noted that Inuit indigenous knowledge led to the discovery of one of the ships of Sir John Franklin, who set out to find an Arctic route around North America in 1845. Both Franklin's ships and all of his men were lost, and though Inuit accounts of the tragedy at the time were widely disbelieved and denounced, they ultimately proved to be correct and led to the discovery of one of Franklin's ships in September 2014 (Fahrenkamp-Uppenbrink 2015). Similarly, Jean Polfus used traditional ecological knowledge of the Dene First Nation to study the morphological, genetic, and ecological variability of three species of Caribou in the Canadian Northwest Territories (Merkle 2016).

Indigenous knowledge also has relevance to archaeology. The Society for American Archaeology's the *SAA Archaeological Record* devoted an entire issue to indigenous knowledge and its role in archaeological practice (Whitley 2007). Ethnoecological studies of plant use and forest use in Belize have shown that the

Maya subsistence practices reveal their long-term management of the tropical forest (Ford 2008). Indigenous knowledge has also been used to identify archaeological sites in dense tropical forest and to enhance local history for local indigenous populations (Duin et al. 2015). Kelli Carmean et al. (2011) have suggested that local indigenous knowledge, based upon the different types of stone gleaned from the Maya Cordemex Dictionary, indicate that different Maya classifications of stone were differentially distributed within and around Sayil and that high-quality construction stone may have been a natural resource that was controlled and distributed in a manner similar to water and land. Besides providing a description of ancient Maya perceptions of soil, land and earth, Christian Wells and Lorena Mihok (Wells and Mihok 2009) summarized contemporary and ethnohistoric classifications of these phenomena, providing a substantial contribution to those interested in Maya agricultural development.

The use of Maya dictionaries is an important and innovative way to understand the perceptions of the environment of the ancient Maya, but it is only a first step and can miss semantic variability. Dictionaries are no better than the specialized knowledge (or lack thereof) of the informants used to produce them. When meanings are specific to specialists such as potters, masons, and swidden agriculturalists in local communities of practice, however, understanding Maya traditional ecological knowledge must be understood with reference to specific local communities, their unique landscapes, and the variability of the raw materials found within them. Any description of Maya perceptions of their environment and raw materials is, of course, important for understanding ancient Maya culture and modern agricultural development, but classifications vary from place to place, from ethnic group to ethnic group, and from the present to the past. As this work shows, classifications of the landscape and the raw materials from it are specific to distinct communities of practice. There are, of course, commonalities between such communities in the present and those in the past as the works cited above have shown, but classifications appear to be specific to communities of practice that are bounded by local landscapes and internal interaction. Moreover, such classifications are unique to specialists in a community that use those resources. A close examination of Raymond Thompson's classic work (Thompson 1958) on Yucatek Maya pottery making, for example, reveals that though he tries to lump local classifications into larger behavioral units such as clay, temper, and paint, his detailed descriptions of the local variations indicate that each pottery-making community in Yucatán recognizes different Maya classifications of raw materials, defines them differently, and uses them in unique ways. This observation indicates that though variability exists within communities of practice, there is less variability within a community in the labeling and the selection of raw materials than there is between communities.

The study of craft production of a specific community of practice is, of course, critical for archaeologists because inferences of ancient pottery production are loaded with assumptions about the distribution of craft resources, or lack of them, how pottery is made, how production is organized, how technology (and its products) are transmitted from culture to culture, and how pottery relates to the populations that made and used it. Further, the study of craft production and the indigenous knowledge about it can reveal great insights into the past, not just about ceramic production, but for all crafts as well. Unfortunately, many archaeological descriptions of ancient craft production seem to exist in a parallel universe that is largely unrecognizable from the perspective of the actual knowledge and practice of crafts such as pottery making.

Critical to the study of crafts is how potters engage their landscape in order to produce pottery. What kind of knowledge do they embody about the natural world around them, about the materials that they use, and about the process by which they turn these materials into finished vessels? How do they engage their world using this knowledge?

These questions may seem to be simple and obvious to an archaeologist with equally simple and obvious answers. Although the ethnographic and ethnoarchaeological literature is filled with descriptions of what potters do and what they make, there is little emphasis about how they think, how they perceive and classify the world around them, and what they know. Many of the descriptions include the native words for raw materials and vessels, as well they should, but such references represent only the tip of the iceberg of what the potter knows, both consciously and unconsciously.

Knowledge, however, is not behavior, and anthropologists for generations have recognized that what humans say they do, and what they actually do, are not necessarily the same. Rather, actual behavior may vary from stated practice (Lauer and Aswani 2009), and actual outcomes may vary from the rules of behavior (Johnson 1974). This is no less true for pottery production than it is for ethnoecology and the study of kinship (Gillespie 2000a, 2000b, 2000c). My own description of patterns of kinship, inheritance, and residence among Ticul potters, for example, does not reflect elicited rules or verbal responses, but rather resulted from my deep experience of more than four decades of personal knowledge of individuals, their relatives, the composition of their households, and the changes, or lack thereof, of the locations of these households (Arnold 1989; 1991; 2008, 31–91; 2012; 2015a). These patterns were verified by records of birth, marriage, and death from municipal and church records as well as by the actual composition of the households over the years. In brief, they represented the behavior of actual household composition and house lot inheritance, not just the ideal rules of such composition and inheritance.

The focus on practice and behavior rather than knowledge has recently become popular and characterized as practice theory (Bourdieu 1978, 1980), but the concern about studying actual behavior is not new (except perhaps in Europe), and has been the concern of anthropologists in America for decades. In reality, both the knowledge *and* the practice of crafts need to be the focus of study in order to understand them holistically and to apply them to the remote past.

POTTERY PRODUCTION AND PARADIGMS

Like anthropology itself, the study of ceramics has been fraught with changing theories and paradigms that lurch from one perspective to another. Paradigms are constantly replaced by other, newer, more fashionable ones. Cognitive anthropology (D'Andrade 1995), cultural materialism (Harris 1968, 1979), cultural ecology (Steward 1955), ceramic ecology (Arnold 1985; Kolb 1976, 1988, 1989; Matson 1965a, 1965b), technological choice (Lemonnier 1986, 1992, 1993; Sillar and Tite 2000; Van der Leeuw 1993), *habitus* (Bourdieu 1978; Mauss 1976), behavioral chain analysis (Schiffer 1975, 2005; the *chaîne opératoire*), practice theory (Bourdieu 1978, 1980), and engagement theory (Malafouris 2004, 2013; Renfrew 2004) have all been advanced as presumably novel and exciting ways to describe what people know, what they do, and why.

No theory and paradigm, however, have an exclusive corner on explanatory validity. Most are limited, focus on one aspect or another of human behavior, and usually cannot incorporate opposing views. Nevertheless, they are not, as some would have us believe, in competition with one another and are best understood as additive. Rather, like the proverbial apples and oranges, they are incommensurable and complement and explain different aspects of the phenomenon being studied like the metaphor of the blind man and the elephant. Any craft such as pottery making, like the remainder of human culture, needs to be embraced and studied holistically. Technological choice, for example, is not incompatible with an ecological approach in which potters receive information from the environment, their raw materials, and the pottery-making process in order to make their pottery (Arnold 1985) as some have claimed (Gosselain 1998, 79–82; Loney 2000; Van der Leeuw 1993). All can contribute significantly to a holistic understanding and explanation of ceramic production and distribution and its variability. Different paradigms and theories of ceramic production all have truth value and need to be integrated together into a unified whole.

All of these approaches to the past have value, but the study of material culture should not be simply subject to the theoretical fads and then discarded when paradigmatic fashion changes. Emphasizing each new paradigm in order to appear "trendy" or "in style" (see Arnold 1991), and ignoring the value of previous ones, suggests that there is no objective, verifiable truth, that truth about the past is merely relative to the observer's position and has no transcendent value beyond the theoretical fad at the moment. For those archeologists who believe that the past has an objective reality that exists beyond our ability to adequately know and describe it, focusing exclusively on such a relativistic stance challenges the notion that there is such a thing as a real knowable past—albeit one that can never be described fully nor completely.

Some archaeologists spend time affirming the obvious that objects have meaning, that they affect behavior, that humans have agency, that ideas are reflected in material culture, and that the technology is embedded within a social and political structure. These notions are elementary and obvious to anyone with anthropological training and ethnographic experience, and probably to any thoughtful person. It is obvious that humans materialize ideas and semantic structures in material objects and that cognition is reflected in material culture because of human agency and that technology is socially embedded. What is significant about these truisms is not that they exist or are new, but rather that anthropologists need to figure out how they are manifested and applied in a particular time, place, and circumstance.

Some modern paradigms merely dress up traditional ideas in new terminological clothing. Some of this new terminology provides a vocabulary to talk about these ideas, but one should not be mesmerized with their seeming novelty and newness. That being said, engagement theory is an encompassing explanation that can incorporate a number of paradigms that tie human agents formally to material culture in new and thoughtful ways by recognizing both the action that humans have on the material world, the resulting artifacts, and the reflexiveness of that world, the artifacts, and their context, on human knowledge and action.

ENGAGEMENT THEORY

This book presents indigenous knowledge of Maya potters of Ticul, Yucatán, from the perspective of engagement theory. Still in its nascent stages, engagement theory has the potential to be a truly unifying theory for the study of material culture and ceramic production by incorporating many different perspectives. As described by Colin Renfrew (2004) and Lambros Malafouris (2004, 2013), engagement theory concerns itself with the relationships between humans and the material world that stress the knowledge-based nature of human action, and the reflexiveness that the material world exerts on the mind.[1]

Engagement theory, like cultural ecology (which also deals with relationships) is also holistic and unifying, but rather than focusing on how cultures choose to adjust to environmental, social, and political conditions, engagement theory provides a different emphasis. Rather, both Colin Renfrew (2004) and Malafouris (2004, 2013) are concerned about the effect that artifacts ("things") have on humans and upon their minds, recognizing that the human mind extends beyond the brain.

Why Engagement Theory?

Learning to make pottery depends upon engagement with the material world, and a theory about that engagement has the potential to draw together different strands of cognitive anthropology, cultural ecology, notions of *habitus* (including motor habits), technological choice, behavioral chain (or *chaîne opératoire*) analysis, data from the landscape, and the inherent characteristics and constraints of the raw materials. This work thus is an attempt to combine such approaches into a coherent whole to describe the traditional knowledge of the Maya potters of Ticul, Yucatán.

In some respects, material engagement theory is more useful in ethnoarchaeology than it is in archaeology and needs to be more rooted in the actual engagement with artifacts in the empirical world of ethnography before it is applied to the past. This approach is not always possible, but it is possible with technological processes such as making pottery because the basic behavioral chain (*chaîne opératoire*) of making pottery is isomorphic between the present and the past. Production follows the same universal sequential process of procuring raw materials, preparing them, mixing them to make the paste, forming them into a vessel, and then drying and firing them. This sequence transcends space and time, even though there is great variability in each of these steps with behavioral sequences within them that have social significance. Further, based upon ethnographic cases among societies throughout the world, there are highly probable limits to distances to ceramic resources, constraints on production intensity by weather and climate, the amount of drying space available, and the effect of the degree of sedentariness on pottery production that can aid the archaeologist in interpreting the past (Arnold 1985, 2015a, 243–76). In this sense the process of making pottery has at least some material agency in its production (see Malafouris 2013, 207–26). As both Malafouris (2013, 20726) said and Tim Ingold (2013) illustrated throughout his work with examples from architecture and basket making (among other activities), the engagement of the material world involves both human and material agency.[2]

Engagement theory can provide a useful approach to describing potters' indigenous knowledge that relates to many of the themes of contemporary archaeology. To do so, one must understand the way that potters categorize their raw materials, the culturally relevant characteristics of those materials, and their sources in the landscape (e.g., Arnold 1971). It also takes into account the role of the environment and landscape in providing choices for production (cultural ecology and technical choices) and the actual physical properties of raw materials learned by the potter. Further, engagement theory can take into account the habitual nature of human cultural behavior. Although part of this notion is *habitus*, there is a firm physiological basis for habitual working postures and muscle syntax (e.g., motor habits). Finally, engagement theory has the potential to incorporate feedback (Arnold 1985, 1–19) from aural, visual, and tactile *percepta* derived from the potter's interaction with the raw materials, the behavioral chain of the pottery-making process, and the language of other humans. The notion of feedback developed in *Ceramic Theory and Cultural Process* (Arnold 1985), for example, was one way of describing the engagement of potters with the social and natural environment that recognizes that they are agents, that they are not oblivious to the social and natural world around them, and that potters recursively receive information (feedback) from it in a way that affects the pottery-making process. The point of that book was to restore a neglected perspective to ceramic studies that potters live and work in a natural world—not just a social, or socially constructed, one—and that the natural world of making pottery (e.g., weather, raw materials, and the process of making pottery itself) has some material agency in its production. Pottery nevertheless still embeds and materializes relativistic social and cultural patterns, but those aspects of production can be inferred more credibly if the material agency of the raw materials and of the process is understood first.

I am attracted to engagement theory because of my experience participating in the practice of making pottery when I came to understand the way in which potters engaged the behavioral chain of pottery making. First, by participating in the process of mining and selecting raw materials, I learned how to select raw materials and then selected them myself, thus understanding the way in which the potter engages both the landscape and the raw materials in it. Further, my experience with the material agency of weather and climate in Peru (Arnold 1975a; 1985, 61–98; 1993, xxiii–xxvi; 2011), Yucatán (Arnold 2015a, 243–76) and in Guatemala (Arnold 1978a, 336, 338–39, 341–42, 346–47, 351–53, 357, 365, 369, 371, 380, 384) showed me that failure to take weather into account may lead to erroneous conclusions about inferences of the intensity of craft production in ancient societies. Intensive pottery production cannot be done full time during a period with heavy rains and damaging winds without great changes in the potters' built environment (Arnold 2015a, 243–90). This perspective only occurred to me in retrospect after deep reflection on my field experiences and on the lack of pottery production during the rainy and hurricane season.

From this engagement, I learned lessons about the procurement process that I would not have understood as deeply had I not participated in it. When geologist

B. F. Bohor and I visited the clay mine at Hacienda Yo' K'at in 1968, we crawled through an entrance tunnel that was barely fifty centimeters wide and twenty centimeters high (Arnold 2008, 175; Arnold and Bohor 1977). It was so small that I had to move through it on my stomach with arms stretched out in front, propelling myself forward by the action of elbows and toes. As my toes dug into the bottom of the tunnel, my heels simultaneously scraped its ceiling. Although the tunnel opened up inside the mine into a large excavated room, getting there was not for the claustrophobic. The air was bad, and the audio recording that I made there revealed my rapid breathing. Reflecting on this experience afterward proved to be psychologically traumatic. When I showed slides of the interior of the mine to my classes and played the audiotape made there, it had devastating effects on my mental state. Nightmares about claustrophobia in the mine and the potential danger of its collapse plagued me for years afterward. ("Things" really do change the mind!) Nevertheless, experiencing the embodiment of the technology and engaging in the mining process enabled me to learn firsthand about the experience of a clay miner. As traumatic as my experience was, engaging in the actual practice of the technology created a genuine understanding of the great challenges and dangers of underground clay mining (Arnold 2008, 15–16, 158). After hearing about several deaths and near fatal accidents in the clay and temper mines during the course of my research from 1965 to 2008, I realized how dangerous such mining can be. My engagements illustrate how one cannot truly understand technological practices unless one actually participates in them (Arnold 2008, 15–16), a point also made explicitly and implicitly by Ingold (2013).

Visiting the Ticul clay source again in 1984 also provided a stimulus to reflect on the importance of bodily engaging in the technology of clay procurement. By this time the 1968 mine was abandoned, and clay was extracted through a series of vertical shafts sunk approximately three to five meters into the ground to reach the clay layer. I lowered myself into one of these shafts, as miners had instructed me, by wrapping the rope around one hand, grabbing the rope with the other, and using the footholds on the shaft wall to provide support for my body as I changed hand positions on the rope.

Climbing out of the shaft was much more difficult. Using the rope to raise myself from foothold to foothold was a daunting task, and I had to rest frequently by placing my back against the side of the shaft by pushing my feet against the opposite wall.

Miners had insisted that I remove all my clothes except my underwear to descend into the shaft, but I refused and only removed my shirt. When I ascended the shaft, however, I had to force my back against its wall as I pulled myself up the rope. In doing so, I loosened a considerable amount of marl behind me that was forced into my jeans and shorts because of the horizontal or near-horizontal position of my legs used to move me up the shaft. By the time I reached the top of the shaft, I was carrying considerable extra weight. In order to remove the marl from my jeans and underwear, I had to take off all my clothes anyway and then had to put them on again—soiled from my descent into the mine. The miners, however, only needed to remove their underwear to empty them of any marl that had accumulated in them, but they donned clean clothes—untainted because they did not wear them during mining (Arnold 2008, 15–16, 172–80). The miners' advice took on a new meaning after I descended into the mine myself. Rather than having just a dirty body that could easily be brushed off like the miners did, I had a dirty body and dirty clothes and had expended unnecessary energy in carrying marl up the shaft in my clothes!

In examining the images of my earlier visit to the clay mine in 1968, I noticed that the miner that accompanied us wore only underwear. This seemingly strange behavior finally made sense to me. As a result, I was able to gain insight into the daunting task of going up and down the shaft into the mine and raising the raw clay to the surface (Arnold 2008, 170–80).

This experience also taught me that clay mining in the shafts could not be done by a single miner, but required two men—one to mine the overburden and clay in the shaft and another to raise it to the surface. I had noticed that miners worked their shafts in two-man teams, but going down into the mine myself revealed that a single miner working in the shafts would be difficult if not possible, and such shaft mining was best accomplished by a two-man team.

When my visit to the clay mines in 1984 ended, the miners offered my informant and me a ride on the truck that transported the clay back to Ticul. In the morning we had ridden bicycles the approximately six kilometers to the mines within Hacienda Yo' K'at, and I remembered how relieved I was that did not have to ride my bicycle back to Ticul in the heat of the day. So, we placed ourselves and our bicycles on top of the load of clay, and the truck took us to my informant's house in Ticul. This seemingly simple act was a great relief, but it also made me appreciate the role of the distance traveled to clay sources and how difficult it must have been to carry virtually any amount of clay back to ancient Ticul (San Francisco de Ticul, see chapter 8) on one's back during the Terminal Classic Period (see Arnold and Bohor 1977).

I had a similar experience during my first trip to the temper mines in 1965 except that two informants and I rode bicycles to the mines during the heat of the day in the hottest season of the year. Even as a young man of twenty-two, I found the bicycle trip exhausting and was pleasantly surprised that we didn't have to bring the sacks of temper (probably weighing more than 30 kg) back with us on our bicycles (Arnold 2008, 217). Rather, informants left the sacks of prepared temper for a hauler to bring them to the potters' houses with his horse cart. If they had carried the temper on their backs when they returned to Ticul, the amount that they could carry would probably be less than thirty kilograms, and the trek back to Ticul would have been exhausting.

I also learned how to fire pots by first eliciting descriptions of the process in Yucatek Maya and then doing it by myself under the watchful eye of my informant. The result of this practical engagement aided me in understanding the nature of technological "knowledge," how it is learned, how it is practiced, and how it is passed on to others. After firing five times by myself, I learned just how complicated a seemingly simple technological process can be by understanding the multifaceted nature of human engagement with that process. This engagement helped me bridge the gap between cognitive knowledge of firing and its actual practice, and how the actual practice of firing affected the mind, specifically the cognitive structure of firing.

Similarly, on one April morning in 1965, I got up at 4:00 a.m. to accompany a potter who was taking his water-carrying jars to Oxkutzcab to sell. He had purchased space on a truck that was taking ice from the factory in Ticul, and the truck owner rented space to the potter to transport his pots. After we arrived I watched him bargain with buyers and then sell his remainders at a discount at midday so that he would not have to pay the additional cost of transporting his vessels back to Ticul.

My experience with the embodiment of knowledge and participation with potters and their craft thus have enriched this description greatly and illustrates why participant-observation is so important in anthropological research. Because technology is artifact, activity, and knowledge, actual participation in the culture permits a degree of understanding beyond questioning, verbal interaction, and observation. It provides a foundation for understanding the engagement of the potter with the craft and the sale of his products.

The lack of actual engagement as a participant-observer in the pottery-making process is one reason some archaeologists have a difficult time understanding ethnographic perspectives such as those embodied perspectives of sensory feedback presented in works such as "Ceramic Ecology of the Ayacucho Basin, Peru: Implications for Prehistory" (Arnold 1975a, 1975b), and *Ceramic Theory and Cultural Process* (Arnold 1985). Some do not understand why the effort required to carry more than thirty kilograms of clay from the source to their houses for more than five kilometers is so difficult, because they have not done it themselves. These are some of the reasons that I find archaeological descriptions of pottery production and their relationship to ancient society so incongruent with my own experience in studying pottery making in Yucatán, Guatemala, and Peru. Some archaeologists have not had the experience of actually studying or working with the potters in the field themselves and have never bodily engaged the craft enough to see the material agency of the process and its environmental context. As both Ingold (2013) and Malafouris (2013, 207–26) have shown both experimentally and theoretically, actual engagement of the archaeologist in artifact production does reveal a different and unique perspective that is helpful in understanding the production and use of material culture.

COMPONENTS OF THE THEORY

Although greatly influenced by the insights, perspectives, and theories of Ingold (2000, 2013), Renfrew (2004) and Malafouris (2004, 2013), what follows does not engage those perspectives in detail. Rather, like my other work on pottery production, it follows a synthesis based upon my own experiences in the pottery-making process with limited theoretical jargon yet without losing the importance of linking theory and data. This presentation thus is more of a grounded theory, based first on my own description and engagement in the pottery-making process of Ticul and elsewhere, and then using some of the theoretical concepts in order to try and understand that engagement from a theoretical and generalizing perspective.

The Behavioral Chain (The *Chaîne Opératoire*)

If engagement theory is holistic, what are its components? First, engagement theory must include an understanding of the universal dimensions of the behavioral chain of pottery making. This sequence of activities is unique to making pottery because it follows from the unusual characteristics of clay minerals that require a fixed sequence consisting of obtaining raw materials, mixing them, adding water, and then shaping, drying, and firing them. Although the general sequence is fixed by the nature of the raw materials and the desired outcome of the final fixed form, there are numerous choices within each link of the chain. Some of these have material agency in the practice of the craft; others do not, but reflect cognitive agency influenced and modified by cultural, social, and individual factors. There are also subsequences within this master sequence that reflect individual, social, and cultural patterns that are not influenced by the material constraints of the raw materials or the pottery-making process.

The material agency of raw materials and of the pottery-making process often appears to be excluded or ignored—particularly in discussions of technical choice and the *chaîne opératoire*, as if there was no material agency at all. Making a usable paste to form pottery requires enough plasticity to form a vessel, but not so much that the shape will sag after forming. So, functioning nonplastics must be added to reduce plasticity. Then, the paste is fabricated into vessels, and then they must be dried carefully. This loss of water in the paste is a critical step in the process, and thus the humidity, temperature, and the amount of sunshine affect successful completion of the pottery-making process (Arnold 1985, 61–98). These conditions may exist in the natural environment, or they may be the result of changing the built environment to increase covered space and using special drying areas such as shelves in order to protect the pottery from the damage resulting from risks of inclement weather and those from household activities such as playing children, domestic animals, and clumsy adults (Arnold 2015a, 243–76).

The Semantic Structure of Knowledge

The second component of the theory involves the semantic structure of indigenous knowledge that is reflected in language. Language is the users' guide to understand potters' engagement with their landscape, their raw materials, and the pottery-making process. I originally approached the potter's craft through the language of the potters (Yucatek Maya) in which my informant structured the description of ceramic technology through questions that he formulated. This began even before I knew Spanish and was possible through a technique known as ethnoscience (described in the next chapter). Using this technique, I eventually learned the Maya names and indigenous semantic structure of Yucatek Maya ceramic technology that were part of the potters' indigenous knowledge.

Understanding the semantic structure was critical for understanding the native categories used in making pottery. Categorization is an integral part of human epistemology, foundational to any culture, as well as necessary for any serious scientific study. So, engagement theory should take into account the way in which the potters categorize their environment, their raw materials and their sources, and their characteristics. This categorization does not just proceed one way from the mind to the object but, as Malafouris has pointed out, involves the influence that the external world (the environment, landscape, raw materials, and pottery-making process) has on those categories. Native categories of phenomena are critical because if one also wants to approach pottery through the perspective of technical choice and discover the potter's choices, one cannot do that unless one knows the options.

In Ticul, some of the potters' semantic categories are general cultural categories known to others in the culture, but potters also utilize specialized classifications that come from their unique engagement with the process of making pots. Such knowledge is learned through experience by engaging the environment, the raw materials, and the production process itself. In many cases these categories are labeled in the native language and consist of their classifications of ecological zones, rocks, clays, tempers, firewood, vessels, parts of vessels, parts of the kiln, and parts of the firing process. The community of potters in Ticul is thus a community of practice circumscribed by potters' own interaction and by the unique landscape that they engage. It is different from other communities of practice in Yucatán that make pottery (such as Mama and Tepakán), are different interacting populations, have virtually no contact with Ticul potters, and engage a very different landscape to obtain their raw materials.

Ticul potters, for example, describe clays by the five color terms that are used in all Maya languages (Berlin and Kay 1969), but they use other more specialized categories that cut across these colors (see chapter 4). They separate high-quality clay for making pottery from ordinary clay that is not used for making pottery using properties such as taste and the manner in which the clay dries. Similarly, potters use a major class of raw materials (temper) that has the same Maya term as a widely available calcareous marl, but which they differentiate by the source from which it comes and by the presence or absence of a critical ingredient they call "white earth." Similarly, though potters share the knowledge of the categories of firewood with Maya swidden agriculturalists, they have specialized knowledge about the wood, such as speed at which each burns, the height of its flame, and whether it burns with a lot of smoke.

The culturally relative nature of these cultural and linguistic categories raises a significant issue in using them across time and space. As interesting as they might be, their usefulness for understanding the technology and for doing archaeology is limited. How can such categories be applied to the past? This study thus engages the knowledge of the potter from both the emic and the etic perspectives (Harris 1964; 1968, 568–604; 1990; Headland et al. 1990; Lett 1990; Pike 1990) that reflect complementary epistemological and methodological approaches to human culture. If one relies on verbal data, one's ability to generalize cross-culturally will be limited. Verbal data is, of course, better than no data at all, but the emic categories obtained by verbal data should be related to etic units of observation if they are to have any validity across time and space. Furthermore, etic and emic perspectives provide complementary viewpoints that enhance understanding technologies in the present, and provide a translation of the potters' technology useful in studying the past, and an epistemology for comparing it with that of other cultures in the present and in the past.

Another way of looking at the complementary perspectives of emic and etic epistemologies is to see the emic perspective as what potters say and the etic perspective as what they actually do. Further, the etic perspective thus does not just involve the translation of the emic categories, but rather is also the material results of actual practice. The results thus can be represented as scientific categories by using units of observable behavior such as minerals and chemical elements. Emic and etic approaches, however, are only ways of knowing and are not the same as actually engaging the pottery-making process. Furthermore, understanding etic categories (scientific knowledge) is not an attempt to validate useful indigenous knowledge (Brouwer 1998), but simply a way of translating indigenous (emic) categories into meanings that can be more easily understood in a different cultural context and used in the study of the past.

Customary Muscular Patterns

Engagement theory should also take into account the habitual nature of human culture called *habitus*. *Habitus* consists of at least two different aspects. First, it includes customary and habitual muscular patterns that come from repeated behaviors such as working and carrying positions (Arnold 1985, 147–50; 2008, 236–37, 240–42, 244–45). Marcel Mauss (1976) first noted that different muscular patterns existed among cultures of the world, and he called these patterns *habitus.* Gordon Hewes (1955, 1957), motivated by Mauss's work, classified worldwide postural patterns and found that over 1,000 were possible and that certain ones were common to particular regions. Hewes did not use the term *habitus*, but rather recognized them for what they were: postural patterns. Although not clearly influenced by Mauss, Robert Spier (1967) expanded the notion of working postures to include muscular patterns of motion called motor habit patterns. Arnold (1985, 147–49) applied the notion of motor habits and postural patterns to ceramic production and pointed out how these traditional patterns can inhibit the introduction of new technology such as the wheel (Arnold 2008; Arnold, Wilson, and Nieves 2008). Pierre Bourdieu (1978) reintroduced the term *habitus*, one that involves the nature of muscular patterns of position and action that were habitual. Bourdieu's use of the term, however, is broader than muscular patterns of position and action, but American anthropologists sometimes use as a simpler term. It simply appears to be the power of habitual ways of thinking called "tradition."

Muscular patterns are social in that they are learned from others, are reinforced by furniture and the lack thereof, and are consistent across different activities in a culture (Arnold 1985, 147–51; Spier 1967). With respect to pottery production in Ticul, potters work either squatting to mix the paste, or seated on the floor, or on a low stool (a *k'an che'*) to form the pottery on a turntable. As is true with work patterns in general (Arnold 1985, 147–48; Spier 1967; see also table 6.3, this volume), the postural and motor habit patterns of making pottery in Ticul are the same as those used for other activities as well. With the location of the hearth on the ground, cooking and tending the fire are done in a squatting position. Further, relaxing, cutting pond fronds, or other activities are all accomplished by using the same squatting position or by sitting on a low stool (see table 6.3 in this volume).

Second, *habitus* also involves sequences of muscle use that have created a habitual syntax of behaviors that are largely unconscious. These sequences consist of the behavioral rules and strategies that combine categories for preparing raw materials, mixing them to make the paste, using the paste to construct a vessel, and firing the vessel to forever fix its shape. These sequences could also be regarded as one aspect of the *chaîne opératoire*. Sometimes these positional and motor patterns are referred to as "muscle memory," but in reality, muscles don't remember; rather, habitually patterned positions and motor habits are the results of the syntax of synapses firing in the brain.[3] This motor learning involves the increased production of myelin, a substance that surrounds and insulates axons in the central and peripheral nervous systems. The increased production of myelin increases the speed of electrical communication among neurons in the brain and hence its computational power (Long and Corfas 2014; McKenzie et al. 2014). One view of why motor learning is habitual is that newly generated myelin is laid down preferentially in circuits that are engaged during motor learning (Long and Corfas 2014; McKenzie et al. 2014). It thus alters the internal neural structure of the brain and results in habitual behaviors. The habitual use of technology and "things" thus really do change the brain just as Malafouris (2013, 119–49, 227–49) argued.

Feedback

Finally, engagement theory ties all of the phenomena of ceramic production together by incorporating feedback. Feedback consists of the information flowing to the human agent from other humans as well as that coming visually, aurally, and in tactile form from the raw materials, the environment, the landscape, and the potter's engagement with the behavioral chain (the *chaîne opératoire*) of the pottery-making process. It is simply the information perceived by human agents from their engagement with the social and physical world in a way that affects their behavior. Feedback also comes from the use of, and demand for, pottery in the form of information when it is used by a population. According to cybernetic theory, this information is not *really* feedback unless it actually affects the agent's behavior or performance or has the potential to do so.

Although first proposed more than sixty years ago by Norbert Weiner (1948, 1954), the notion of feedback or feedback loops has become a widely used scientific concept across many scientific disciplines. A search of the scientific content of journals of the American Association of the Advancement of Science for articles that deal with feedback, for example, returned references to 12,009 articles across all of the biological, physical, and social sciences, and an additional 1,238 articles in their other journals established since 1999.[4]

Feedback has become a common way to express mutually causal relationships across the natural and social sciences with discoveries that use the concept appearing almost weekly in *Science*, the flagship journal of the American Association for the Advancement of Science. A review of how *feedback* is used is beyond the scope of this work, but a brief survey of some articles in *Science* reveals that feedback loops are particularly important in natural systems such as the deviation amplifying relationship of clouds, air-sea dynamics, and ozone-temperature-wind to global warming and climate change (e.g., Clement et al. 2009; Kerr 2009b); the deviation amplifying effect of solar variations on climate variations (Kerr 2009a; Meehl et al. 2009); the mutual feedback between climate change and vegetation (Peñuelas, Rutishauser, and Filella 2009); climate change and soils (Amundson et al. 2015); feedback between the light-dark cycle, behavior, and metabolism (Ramsey et al. 2009; Wijnen 2009); and between behavior, environmental complexity, and movement strategies in mussels (de Jager et al. 2011). Feedbacks are also invoked to describe the complex relationship between fire, rainfall, and vegetation in the transitions between forest, savannas, and grasslands (Hirota et al. 2011; Mayer and Khalyani 2011). A positive feedback loop is also used to describe the social attachment between humans and dogs that is stimulated and modulated by mutually gazing at one another and mediated by the production of increased concentrations of the "trust hormone," oxytocin, in each species. Such feedback is believed to have been involved in the domestication of dogs (MacLean and Hare 2015; Nagasawa et al. 2015).

Negative or regulatory feedback loops have been advanced to describe and explain cellular responses and internal "tuning" (Justman et al. 2009) and the regulation of intracellular stress-induced proteins in *Drosophila* that prevents age-associated pathologies by a variety of factors (Lee et al. 2010). Further, regulatory feedback is invoked to describe the effect of human prefrontal cortex and hippocampus on monitoring errors ("mistakes") in learning when a human genetic variant inhibits dopamine uptake in the brain (Holden 2007; Klein et al. 2007).

Similarly, among humans a feedback model has been invoked to describe "system-dependent selection" in which "ecological feedback in a dynamical system can lead to environmental regulation, stable phenotypic diversity and an increase in mean fitness" (Lansing et al. 1998). Gregory Bateson (1958, 287–90) used the notion of feedback for what he called "circular causal systems." Malafouris (2013, 225) uses sensory feedback to describe the engagement of the potter with the clay, and Arnold (1985) has used it to describe what is now known as the material agency between pottery raw materials, the process of making pottery, weather, and a host of cultural patterns that result from the engagement of the potter in pottery production. The feedback mechanisms described in *Ceramic Theory and Cultural Process* can be viewed not only as mutually causative mechanisms for the relationship of pottery, environment, and society, but also as factors that have material agency in the pottery-making process, its seasonality, and its implication for production (see also Arnold 2011), just as Malafouris (2013) argued that the material world external to the brain can profoundly affect and change the "mind" and can be viewed as an extension of it.

Feedback for humans is, of course, different from that of natural systems in which relationships are activated by internal triggers. Unlike in nonhuman systems, humans obviously make choices, and they can choose whether or not to use the information coming from the raw materials, the pottery-making process, the weather, and the demand for vessels. If they choose to ignore this information, however, they may jeopardize the use of their craft to supply their subsistence needs. If, on the other hand, they choose to accept such information and act on it, potters must have either prior long-term memory, experiential knowledge, and working memory to deal with it, and have a problem-solving ability in order to incorporate the feedback coming from the pottery-making process to complete a pot successfully.[5]

When potters engage their craft, the information for producing pottery does not just flow from their mind through their muscles and the syntax of body movement for shaping the paste. Rather, consonant with engagement theory (Arnold 2008, 13–17; Malafouris 2004, 2013; Renfrew 2004), information about the raw materials and the process itself also flows from potters' senses back into their brains, where they make decisions about paste preparation, fabrication, shape, decoration, and firing. This feedback thus is not just a way of describing the multiple and mutually causal links between cognition, behavior, and objects, but it also has a certain ontological validity: it occurs in the minds of potters with information coming from the senses, and they must make choices based upon it. Malafouris (2013, 119–49) calls this "material agency."

On a macroscale, this kind of information flow has been documented and elaborated elsewhere (Arnold 1985) and can be described as a series feedback loops that provide information that the potter can use in making choices in the production process. When such feedback from the performance characteristics of the production process (usually from information through sight, taste, and touch) reveals that some problem has occurred, the potter must modify her behavior in order to achieve a desired result. This recursive information flow thus enables the potter to make and distribute her pots successfully (Arnold 1985).

I have seen this kind of engagement of the potter again and again in Ticul since 1965. Potters, for example, may unknowingly add inferior temper to their paste and, seeing the problems that it has caused, modify the performance characteristics of the paste by adding more *sak lu'um* (palygorskite) to it (Arnold 1971; 2008, 204–12). During the firing process, potters may face problems with excess blackening of the pottery or the failure of the wood behind the pots (i.e., the *pach k'aak'*) to burst into flame at the right moment. Throughout the entire production process, potters are receiving information from their senses, and they must make behavioral choices to ensure a successful outcome (see Arnold, Wilson, and Nieves 2008). Such information flow does not in itself cause changes in potters' behavior (as some believe), but rather provides information for them to make decisions to maintain or change their behavior in order to successfully complete the pottery-making process. This same pattern of feedback from technological processes in the process of firing occurs in the Tuxtlas in Mexico (Pool 2000), in Peru (Arnold 1972a; 1993, 106–7), and in Guatemala (Arnold 1978a), though not always described as such.

Some technological choice proponents, however, appear to argue that feedback related to raw materials and the weather is deterministic (e.g., Loney 2000; Van der Leeuw 1993). Environmental determinism, however, has not been a part of anthropology for more than a century (see also Arnold 2008, 11–13). The notion of choice, on the other hand, is really an old concept in anthropology. In his classic work *Theory of Culture Change*, Julian Steward (1955) recognized that societies and their members made choices to adjust to the environment, and that the task for the anthropologist was to discover what those choices were. Do potters, for example, have a narrow range of choices or a broad range of choices? As I stated over forty years ago: "Environment does not determine the occurrence of ceramic production, but provides choices which either favor or limit the development of pottery making and its evolution from a part-time to a full-time activity" (Arnold 1975b, 201). Rather, as potters engage their environment, their experience has provided them with the knowledge that certain choices have adverse consequences, and they use that information to make decisions about future production. Further, the environment, far from a passive backdrop for ceramic production as some technological choice theorists appear to believe, exerts selective pressures over time on those choices that are viable and those that are not viable. To use Malafouris's perspective, one aspect of the engagement of the potter with his raw materials consists of "material agency" of the raw materials, the environment, and the production process.

If potters make their vessels during rainfall, fire during rain, or lose all of their unfired pottery because of a hurricane, they soon learn that choosing to make, dry, and fire their pottery during wet weather is futile, or they build structures to shelter the process until rainy weather passes (Arnold 2015a, 243–76). Potters would regard anyone who chooses to ignore the adverse consequences of drying and firing pottery during rainy weather as foolish, naive, or stupid, even though sometimes they must fire in such circumstances because of their need for subsistence returns.

In such a case, they try to dry their pottery as much as possible in a sheltered environment and wait, if they can, to fire it on a relatively dry day.

Pottery requires drying before firing, but how much and under which conditions is highly contextual (see Arnold 1985, 61–98; Rice 1987, 152–53; 2015, 152–53). Potters can choose to make and dry their pots outside in the rain, for example, but if they do so, they are foolish and are wasting their time. The generalizations about drying thus involves understanding of the daily and seasonal patterns of weather because it inhibits the physical and molecular processes of making, drying, and firing clay objects. More important for archaeologists, however, is the availability of sufficient space to dry their pottery to avoid damage to it (Arnold 2015a, 243–76). The more objects that potters make in adverse conditions, the greater the amount of covered space that they require. This generalization has direct correlates for the archaeology of production space.

Another source of feedback comes from the embodiment of habitual tasks such as energy use. If potters use their own bodies for transporting clay and temper, their energy expended is not limitless, and the feedback from carrying a forty-kilogram sack of clay more than one kilometer affects their choice of source and type of raw material (Arnold 1985; 2008, 153–89; 2011). The amount of energy carrying clay and temper doesn't determine location of production as some archaeologists believe (Kelly, Watkins, and Abbott 2011).[6] Rather, as I have said before, the distance to ceramic resources are probabilistic and require some understanding of statistical probabilities (Arnold 2005b, 2006; see also Arnold 1991) that are consonant with a statistical "power law" (Arnold 2011). Over time, the energy costs of transporting clay and temper exert a selective force against traveling more than seven kilometers to obtain raw materials except under conditions of animal, motorized, or water transport that extends that distance using a similar amount of energy (Arnold 2011). In some cases obtaining pottery raw materials can be combined with travel for subsistence activities or moving into and through a niche with ceramic resources (Arnold 1985, 199–20), and this activity can have the effect of extending the distance to ceramic resources (i.e., an "energy extender"; see Arnold 2011). Further, distances to resources appear to have some regional variability (Druc 2013; Heidke et al. 2007), but within the general ranges of the high frequencies of distances in the model already presented, for reasons that are unclear.

Finally, feedback comes from a variety of social channels that involve anticipated demand and methods of distribution. Potters must have some information from buyers, middlemen, or other potters concerning which pots will be desired and will sell if they are to use their craft to make a living.

Feedback thus is simply the recursive flow of information from the raw materials, the paste, the pottery-making process, the environment context, and demand through the potters' senses. This information influences, but does not determine, their choices

(Arnold 1975a, 1975b, 1985). Potters monitor and evaluate such information to ensure their success in making a pot (D. Arnold 2000), and they may modify their behavior in order to achieve successful fabrication of a vessel (Arnold 1985). Using the notion of feedback simply recognizes that the relationship between social, environment, and material context and humans is not unidirectional, but is recursive with tactile, aural, and visual information flowing back to the potter from the materials, the production process, demand, and method of distribution. The notion of feedback is thus part of the information that influences technological choices. Human agents utilize the feedback from their memory, the behavioral chain, social factors, motor habit patterns, and the social and physical environment in order to make their choices for making pottery. It is the mirror image of materialization and involves at least some material agency that can affect the production of pottery (Malafouris 2013). Both materialization and feedback are necessary to understand the production process.[7]

In my earlier work I argued that the information that flows between the environment, the production process, and the potters (Arnold 1985) provided the basis for making generalizations about the relationship between pottery, the environment, and social and cultural patterns. Although the pottery production is a universal process requiring raw materials, water, temper, forming, drying, and firing, generalizations about that process and their relationships to the environment are still highly contextual and need to be related to the mineralogy of the local clays, the clay/temper mixture, and the local weather and climate.

The one qualification about feedback that was missing from my earlier work (Arnold 1985) was that the information coming from the environment, the raw materials, or the pottery-making process comes through the senses of the potter to his/her mind. In other words, the potter has agency in the choices to act or not act upon the information from feedback. I did not express this as such because it was so obvious to me. I never dreamed that some archaeologists would be so deterministic that they would see my work as being so. Determinism is in the eye of the beholder, but now Malafouris (2013) and Ingold (2013) also recognize the material agency in artifact creation. Further, one cannot be a participant-observer with potters and not recognize their agency. Only those who have not had this experience can call the effect of weather on making pottery, and the sagging and broken pots that result from it, as being deterministic.

Technological Choice

Recently, scholars have tried to emphasize the importance of the social dimensions of choice as opposed to the technological basis of choice by separating technological from nontechnological, or social choices. Social choices (or technological choices, depending upon how they are defined) in such instances are those choices made based upon other criteria than the physical constraints of the raw materials and the forming technology (Lemonnier 1986, 1992, 1993; Loney 2000; Van der Leeuw 1993). In reality, however, the physical constraints of the raw materials, and potters' engagement with them and with the production process provide the foundation for many of their choices (Arnold 1993, 106–7; Pool 2000). The result of this engagement means that every forming technology cannot successfully produce every shape as I have already shown for Ticul (Arnold 2008, 229–79; cf. Van der Leeuw 1993). Rather, the forming technology, the plasticity of the clay, the paste, the kind of temper used, and the kind of vessel produced are all interdependent.

All so-called technological choices thus really have multiple causes. Potters learn their options by social means, and they choose to make particular vessels from a combination of their indigenous knowledge about shapes, from feedback coming from social interaction about the anticipated demand for the vessels, from the constraints of the raw materials, and from the process of pottery making itself. Forming a pot is not predetermined or technically based because of raw material or climate restraints, nor are choices exclusively based upon nontechnical (social) criteria, but rather are based upon the interaction with, and the engagement of, motor and postural habits, indigenous knowledge, the raw materials, and the process of making the pot. These are then affected by the feedback of visual and tactile experience with raw materials and the pottery-making process that may require experimentation and modification (Arnold 1978b, 347; 1993, 80). Because the raw materials have different potentialities and constraints for making particular vessel shapes such as the working ranges, and the plastic and liquid limits of clay materials (Rice 1987, 61; 2015, 67–70; see also White 1949 and tables 4.7 and 4.8), different forming techniques work best with specific clay minerals, or combinations thereof.

It is thus impossible to isolate a single cause of any particular choice to make it social, technological or ideological; technical choices involve all of these dimensions in one way or another. Choices of traditional raw materials from Ticul (Yo' K'at and Yo' Sah Kab), for example, could be argued to have a social basis since they come from traditional sources of clay (Yo' K'at) and temper (Yo' Sah Kab), both of which were significant places for potters in the 1960s. Is the reason for choosing these sources then a strictly nontechnological one? The importance of the sense of place of those locations was, of course, a significant explanation, but further analysis revealed that both of these places have unique materials that are superior for making pottery compared to those from other locations (Arnold 1971; see also chapter 3 in this volume). Choices that potters make have multiple levels of explanation. Social choices may have technological reasons as their basis, even though the potters may not know or understand those reasons.

This combined social and technological dimension of choice can be illustrated in Quinua, Peru, where design structures reflect both community-based standards of design and the ecological and social structure of the community (Arnold 1970b; 1983; 1984; 1993, 147–96), but with great variability of the choice of design within that structure. Although the potters' choice of design structure, design motifs, and bands would seem to be exclusively socially derived with considerable choice involved, the social organization, irrigation organization, and the socially perceived environment also influence the design structure (Arnold 1983, 1984). To put it differently, the behavioral chain of pottery design has many levels of social, environmental, and technological criteria that are embedded within it. Separation of the social dimensions of choice from its technological dimensions is thus artificial and is the product of analysis, not cultural reality.

Some scholars argue for the determinative role of culture in ceramic production because clay is so plastic and thus reflects the imprint of the culture with no intervening factors. This notion is a flawed assumption and was reviewed and critiqued more than thirty years ago in the introduction to *Ceramic Theory and Cultural Process* (Arnold 1985, 1–19). It has a long history in American anthropology and goes back at least to the early twentieth century. Ruth Bunzel (1929) brought it into the study of pottery, and it was believed that it metaphorically paralleled the notion of the total plasticity of the human personality that emerged from the influence of Freud on the American Culture and Personality School of thought in early twentieth-century anthropology (Arnold 1985, 1–19). Indeed, *Ceramic Theory and Cultural Process* was written to show that pottery was not totally plastic, and the pottery-making process itself also had agency in the cultural patterns necessary in its production. In retrospect, that work was an early statement and example of what is now called "material agency" (Malafouris 2013, 148).

Based upon experimental archaeology and a review of the literature of the previous fifteen years, Tim Ingold (2013) made an identical point in his book, *Making: Anthropology, Archaeology, Art and Architecture*. Material culture, he argued, does not passively reflect makers' ideas or designs, but rather materials are transformed by the maker into a usable product within the constraints of the materials and the technical challenges of the actual "making" process. Malafouris (2013) made a similar point in his detailed elaboration of engagement theory and went further to say that the mind extends beyond the brain and that the external world changes the brain and, by extension, cognition.

Pottery thus is the result of interaction of many factors that enable potters to engage their technology to produce a pot. Culture (or human agency) is certainly one important factor, but it is not the only factor influencing production, instead including many generalizable (nonrelativistic) factors from the natural and social environment. The chemical and mineralogical characteristics of clay minerals, and the process of forming clay into pottery, for example, have generalizable relationships with the pottery-making process (Arnold 1985). Consequently, the potter's choices (and culture) are not simply imprinted on the raw clay but are rather the product of the bodily engagement of the potter and the raw materials involving the potter's training and tradition and his interaction via feedback from the raw materials, the environment, and the process of the emerging pottery product.

THE STRUCTURE OF THIS BOOK

The remainder of this book unfolds the indigenous knowledge of the Maya potter of Ticul with reference to engagement theory just laid out. The next chapter details how the data for this book were gathered. Although much of the data were collected more than fifty years ago, my experience with cognitive anthropology, and its separation from archaeology until relatively recently, meant that the paradigms for presenting this research at the time were too divergent from prevailing paradigms at the time for publication. Part of my problem was my own disillusionment with cognitive anthropology. Eventually, supplementing cognitive categories with a more active engagement in the process of pottery making in the field, I was able to use the Maya categories that I learned, but there was no way to put it all together into a more unified and holistic approach until now. The development of engagement theory (Malafouris 2004, 2013; Renfrew 2004) and Ingold's (2013) description of his students' experiential engagement with making artifacts excited and encouraged me to present my cognitive data along with the experience I gained by actually engaging in the pottery-making process.

Chapter 3 presents the potters' perception of the landscape around Ticul. The details of the landscape—with its culturally defined land forms, forest, and the openings in the landscape—are critical components of the way in which the potter engages the environment to obtain the raw materials to make pottery.

Chapter 4 is an exploration of the Maya potters' ethnomineralogy, the way in which they engage, conceptualize, and classify their raw materials. To make this analysis more relevant to archaeologists and non-Maya, I have also described these data in ways that relate to actual minerals and their physical properties.

Chapter 5 describes the potters' engagement with the changing properties of their raw materials once they are prepared and mixed with water in preparation for forming. In this case, the mental template often regarded as a "paste recipe" is, in reality, at best a rough guide, and the potter must change the amounts of raw materials in the paste as he engages the performance characteristics of the paste. Again, the imprint of a mental template on paste preparation fails as an explanation for how potters make their objects.

Chapter 6 describes the way in which the potters conceived of making a pot and the way in which they produced it. Although Ticul potters produced different vessels in the 1960s from what they do now, the chapter focuses only on the major traditional vessels that potters made in 1965 but were largely abandoned after 1970.

The theme of Maya perceptions and indigenous knowledge of firing is presented in chapter 7 and describes the way in which potters built their traditional kiln and how they named its parts. After an elaborate preparation for firing, potters load the kiln and fire their vessels through a series of named stages and substages using certain types of firewood to achieve the desired effects necessary for the successful completion of the process.

Chapter 8 utilizes the perspective of "pottery as distilled landscape" to synthesize some of the data in this work. This notion originally was developed by Ingold (2000) and then modified as "congealed landscape" by Kostalena Michelaki et al. (2012, 2014). Because of great social and technological changes that have occurred in Ticul in the last fifty years, some of the points in the synthesis are speculative. Nevertheless, it does show that the notion of pottery as distilled landscape has some validity in the rich ethnographic data from Ticul. Because of the uniqueness of its landscape, cognition, and practice of making pottery in Yucatán, the chapter argues that Ticul pottery, before the late twentieth century, distilled portions of the local landscape as a "taskscape" and thus was the product of a unique community of practice circumscribed by distances not exceeding seven kilometers. This application reinforces its value for archaeological contexts as well.

Finally, the conclusion ties the work together and argues for the importance of understanding the engagement of the potter in the making process if one is to understand the past. Showing the value of engagement theory, this chapter applies and summarizes the work as a contribution to refining ideas about technology. It reiterates that the potters' perception of the environment around Ticul and the cognitive categories used by potters in their engagement with the landscape, their raw materials, and the pottery-making process are the product of a unique community of practice is different from that of other such communities in Yucatán.

This chapter also reveals how ethnoarchaeological research among Ticul potters during the last fifty years has enriched Maya Cultural Heritage. Unfortunately, much of this heritage has now disappeared because of great social changes, the changes in demand for many ceramic vessels, and the potters' loss of the Yucatek Maya language.

Finally, the chapter recapitulates Malafouris's notion that cognition extends beyond the brain. Indeed, it is the interaction of cognition with the feedback of landscape, raw materials, and the pottery-making process that gives rise to the semantic categories that constitute part of indigenous knowledge that the potter used to make pottery. That this knowledge has changed verifies Malafouris's idea that "things"—whether landscape, raw materials, or vessel shapes—change the mind. In Ticul, however, this change also results from task segmentation in which potters no longer have direct interaction with the landscape and the market.

NOTES

1. Malafouris's theory is much more complex than that which is described and applied here. In light of the lexical elaboration that he uses in his book, this presentation engages that theory generally. What I have done here is to apply his theory to my own fieldwork experience but without the elaborate lexical semantics. In doing so I have failed to elaborate the detailed richness of his theory, but I hope to have made it clearer and more accessible.

2. Ingold made this point very eloquently when he said: "Human endeavours, it seems, are forever poised between catching dreams and coaxing materials. In this tension, between the pull of hopes and dreams and the drag of material constraint, and not in any opposition between cognitive intellection [*sic*] and mechanical execution, lies the relation between design and making. It is precisely where the reach of the imagination meets the friction of materials, or where the forces of ambition rub up against the rough edges of the world, that human life is lived" (Ingold 2013, 73).

3. Maléne Lindholm et al. 2016 also cast doubt on the notion of muscle memory as a result of muscle-training experiments: "We found no coherent evidence of a skeletal muscle transcriptome memory, even though there were some data indicating a training-induced memory mechanism" (Lindholm et al. 2016, 40). The source of such memory may be in the brain as I have suggested here.

4. These journals included *Science* (11,017 articles), *Science Signaling* (begun in 1999, 992 articles), *Science Translational Medicine* (begun in 2009, 241 articles), *Science Advances* (begun in 2015, 91 articles), and *Science Immunology* (begun in July 2016, 1 article). All but 26 of these articles occurred after 1952, with most of them published since 1977 (http://science.sciencemag.org/search/feedback?, accessed October 1, 2016).

5. Working memory consists of the brain system that is necessary for the concurrent storage and processing of information necessary for complex cognitive tasks such as language comprehension, learning, and reasoning (Baddeley 1992, 556). Standing "at the crossroads between memory, attention, and perception" (Baddeley 1992, 559), working memory consists of the central executive that coordinates the visuospatial sketch pad, the phonological loop, and as more recently proposed, the episodic buffer (Wynn and Coolidge 2010a). To explore these components in relation to the engagement of the Maya potters with their indigenous knowledge is beyond the scope of this work. Suffice it to say, however, that some of the literature on working memory and its proposed relationship to the evolution

of cognition reveals the dramatic role that human engagement (rather than a preexisting mental template) with vocalization, visual images, and action has in the development of the modern human mind (Wynn and Coolidge 2010b). If indeed engagement appears to be so significant in the development of the modern human mind, then is it reasonable, if not obvious, that the relationship between Maya cognition and Maya pottery as proposed in this work is not just the materialization of a mental template, but rather the engagement of Maya cognition with the environment, raw materials, and process of making pottery.

6. Sophia Kelly et al. (2011) believe that the threshold model of ceramic resources is deterministic but provide no evidence that this is indeed the case, and they do not understand the probabilistic nature of the model as evident in the graphical distribution of distances to resources (Arnold 1985) and as a statement of statistical probabilities cited in works published well before their article was published (Arnold 2005a, 2006). Nevertheless, the distances to resources in their case study do precisely fit the curve of my probabilistic model of such distances (Arnold 2005b, 2006, 2011).

7. Flint knapping was the model that was used for the development of the notion of the *chaîne opératoire*. For anyone who has done any rudimentary stone knapping themselves, or watched someone with these skills, visual feedback also occurs in the production of stone tools. Choices, for example, depend upon (among other factors) the results of previous blows to the raw material that are visible to the maker.