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CONTENT MATTERS

The Materiality of Cultural Transmission and the Intersection of Paleolithic Archaeology with Cultural Evolutionary Theory

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THE PROBLEM

With respect to the cultural behavior of other primates, the derived capacity for the complex dynamics of cumulative culture has evolved in our lineage over the last three million years. As Robert Boyd aptly states, this derived capacity "is an essential part of the human adaptation, and as much a part of human biology as bipedal locomotion or thick enamel on our molars."[1] Yet despite the existence of numerous case studies from the Pleistocene *fossil* record on the gradual evolution of bipedality and enamel thickness, the *archaeological* record of the Pleistocene has not provided complementary case studies regarding how this derived cultural capacity *itself* evolved through time. While archaeology has been able to point to changes throughout the Pliocene and Pleistocene in artifact morphologies and the technical complexity of the methods by which those morphologies were achieved (Perreault et al. 2013), it has not provided particularly useful behavioral case studies with quantitative support of the gradual evolution of specific cultural transmission (CT) processes, structures, and scaffolds (sensu Wimsatt and Griesemer 2007).

Paleolithic archaeology should—but is not currently able to—provide data that clarify and characterize early hominin CT processes at different points in time in the past in order to compare and contrast them with the complexity of institutionally diversified cultures found in the present. We should be striving to contribute data to the resolution of questions such as: At different points in human evolution, did the material culture require stimulus enhancement (Charman and Huang 2002; Franz and Matthews 2010; Matthews, Paukner, and Suomi 2010), emulation learning (Tomasello 1996), or imitation learning via triadic attention (Whiten et al. 2009; Tomasello et al. 2005)? When did experienced performers of artifactual skill begin to actively correct mistakes by more novice individuals? Under what adaptive contexts did gestural instruction become significant? In what contexts and when did linguistically assisted instruction play a more important role than observation? When did skill levels in artifact production become diversified enough that particular individuals assumed achieved status as institutionalized role models because of their skill rather than based on other aspects of age, kin selection, or social ranking? What were the structural ramifications of specific behavioral innovations becoming exapted scaffolds for CT, such as the use of fire for storytelling (Wiessner 2014)? What was the population size of the group that could sustain a given level of technological innovation in a specific artifactual medium in a given environment? What can we learn from comparing trends in hominin encephalization with an archaeologically measurable ratchet effect on cumulative culture during human evolution (Donald 1998; Tennie, Call, and Tomasello 2009)?

While we may never be able to answer these questions completely or to our satisfaction, cultural evolutionary theory can only advance if we struggle to engage these central questions, all of which reside at the intersection of many fields, including but not limited to primatology, cognitive science, developmental biology, and population genetics. Yet archaeology is the one field that has access to the physical results of the intergenerational loop between CT and cultural replication that is material culture. And material culture is implicated, if not central, to all of these questions. Archaeologists have engaged with these questions (Pigeot 1990; Karlin et al. 1993; Ploux and Karlin 1993; Grimm 2000; Wynn 2002; Roche 2005; Shipton 2010; Kuhn 2012; Schillinger, Mesoudi, and Lycett 2014; Hiscock 2014), and many have offered carefully argued answers. However, due to the historical rather than quantitative nature of the data traditionally produced in archaeology and the difficulty of connecting our data with bodies of theory from different disciplines (Garofoli and Haidle 2014), it is still possible for two archaeologists to start from basic principles and end up concluding opposed answers. One salient example is the diametrically opposed interpretations of the minimal pedagogical requirements for the most studied artifact in the Paleolithic record, the Acheulean handaxe. Some archaeologists conclude that simple rules of production, acquired without abundant instruction, can produce the variability seen among Acheulean handaxes (e.g., McPherron 2000; Davidson 2010), while others conclude that complex forms of instruction and apprenticeship are necessary for their production (e.g., Wynn 2002; Shipton 2010; Hiscock 2014). Even further outliers, such as Corbey et al. (2016), argue that these artifact forms are as genetically controlled as birds' nests. Without a quantitative and anthropologically sound body of archaeological theory to disprove some of these diametrically opposed hypotheses, there is not much scientific progress to be had within Paleolithic archaeology around the subject of artifactual learning (see additional commentary within Tennie et al. [2017]). We need to develop an archaeology that explicitly addresses the evolution of learning processes, an *archaeology of pedagogy,* to borrow Tehrani and Riede's (2008) term.

The failure to use the quantitative strength of the archaeological record to contribute to answering these questions is a missed opportunity. Paleolithic CT processes were likely to have been simple systems, and studying simple systems in detail can provide an enormously improved understanding of how such processes work in more complex contexts. Studies of Darwin's finches on Daphne Major in the Galápagos Islands demonstrate how the examination of a simple context through time can reveal the workings of a complex process such as natural selection (Grant and Grant 2011, 2014). Evolutionary biologists are in a better position to understand how natural selection works in more complex contexts because of these studies. Paleolithic archaeology should be serving the same role for the development of a comprehensive approach to cultural evolution; nowhere else but in the Pleistocene archaeological record will we find data pertaining to a simple CT context close to the evolutionary appearance of the cultural capacity itself. Studying modern human foragers (Hewlett et al. 2011; Hewlett 2013) and living primates (Whiten, Schick, and Toth 2009; Tomasello et al. 2012) is extremely useful but also limits us to reasoning by analogy and restricts our understanding of how culture *actually* evolved since our last common ancestor with the genus *Pan*.

This chapter describes two obstacles that have caused this unfortunate state of affairs and outlines ongoing research that can move us forward toward solutions. One problem, which I do not count among the two obstacles, is the indirect nature of archaeology as a historical science. Archaeologists excavate data that is indirect when compared with the fossil record; behavior preserves even more ephemerally than bone. Unlike the Grants on Daphne Major, we cannot watch our subjects in real time, and it is debatable whether the significance of these studies would have been realized if the inferences were dependent on the fossil record of finches on the island. Neontology (sensu S. Gould 2002, 778) does have benefits over paleontology. Archaeologists can practice experimental archaeology and ethnoarchaeology, the study of how living humans' behavior forms the archaeological record (Yellen 1977; Binford 1978; R. Gould 1980). However, we are limited to studying only modern humans with their fully developed, institutionalized CT structures, such as fictive kinship (Read 2011), reciprocal altruism via exchange systems (Wiessner 1982, 2002), and scaffolding via storytelling (Wiessner 2014). The hominins responsible for the earliest transmission of material culture, the Oldowan (2.6–1.7 million years ago) or even the slightly older but newly discovered Lomekwian (3.3 million years ago; Harmand et al. 2015), likely did not have any of these CT scaffolds.

OBSTACLES TO A MORE MEANINGFUL CONTRIBUTION OF PALEOLITHIC ARCHAEOLOGY TO CULTURAL EVOLUTIONARY THEORY

Two obstacles are currently making it difficult to utilize the study of the Pleistocene behavioral record for the development of a robust cultural evolutionary theory. The first is the absence of a connection between the types of data produced by most lithic (i.e., stone tool) analysts in the Old World and the cultural learning sets that operate as units of change in CT theory. The second is the overly abstract, nonmaterial nature of how the transmission process is most frequently modeled by the CT community. As a consequence, the transmission process appears far less structured than ethnoarchaeologists and behavioral archaeologists know it to be. I will take each of these obstacles in turn and then explore possible means to overcome them.

Units of Analysis in Paleolithic Systematics

Paleolithic archaeologists tend to structure their data in ways that are inappropriate for studying CT transmission processes, not to mention the developmental complexities of cultural evolutionary theory. From the point of view of the stone tool record, which made up 98 percent of the archaeological record until a few thousand years ago, there are two dominant forms of stone tool data produced by most Paleolithic archaeologists. Within the history of the discipline, the older method focuses on the presence or absence of rarer artifacts and the variations in their morphology, which are interpreted as being highly functional or symbolic, such as large shaped cutting tools (e.g., the Acheulean bifacial handaxes), nodules of rock from which sharp flakes were struck in specific sequences (e.g., cores of particular exploitation strategies such as the Levallois method), and small projectile points (e.g., spearpoints and arrowheads). These "pretty" pieces constituted the (almost fetishistic) focus of research during the youth of Paleolithic archaeology, despite their actual rarity in the record (Monnier 2006).

Ironically, it is these types of artifacts that current lithic analysts most interested in advancing CT research in archaeology have concentrated on over the last twenty years. If one examines the CT archaeology programs begun by Bettinger, Boyd, and Richerson (1996), Bettinger and Eerkens (1999), and summarized nicely in Eerkens and Lipo (2007) and Lycett (2015), it is the study of the variation in these rare shaped objects that has been used to argue for different modes of CT being active at given times and places in the record. Similarly, the phylogenetic and cladistic approaches espoused by O'Brien, Darwent, and Lyman (2001), O'Brien and Lyman (2003), Lycett and von Cramon-Taubadel (2008), Buchanan and Collard (2008), Lycett (2010), Riede (2011), and others have focused exclusively on morphological analysis of such rare shaped objects, rather than utilizing the entirety of stone artifact assemblages to discover the physical evidence of the cultural learning sets that should be the units of analysis in CT research. While I cannot overstate the enormous advances made to date by CT archaeologists through their introduction of new quantitative methods and new theoretical perspectives, their approach is still handicapped by their contentment to studying only the "finished" pretty pieces, the cultural phenotype represented by the final shape of these objects of long use-life. Having drawn their method and theory from paleontology, they seem content to treat the variation in that raw morphology as unproblematic reflections of cultural inheritance, opening them to substantial critique by archaeologists specialized in studying artifactual manufacturing techniques (Bamforth and Finlay 2008). In contrast, I would argue, a cultural genotype exists in the physical behaviors observed and internalized by learners during CT. As these learned behaviors were later physically reenacted in the creation of new objects and so preserved in the resulting manufacturing debris, it is the more ubiquitous manufacturing debris that we should target as better proxies for what the observers learned.

The second dominant form of stone tool data created by Paleolithic archaeologists dates to the 1960s instead of the 1860s and utilizes the entirety of a collection of artifacts, including manufacturing debris, from one geological layer of an archaeological site. Each collection is studied to reconstruct the flintknapping process (i.e., how the stone tools were made) during the period captured within that geological stratum. These reconstructions typically take the form of an assemblage-wide operational sequence, which is the sequence of steps used to reduce raw nodules of stone into cores from which usable flakes with suitable cutting edges were removed and then reshaped for use. Whether produced via the Continental European approach of the *chaîne opératoire* school (for a useful review of this approach, see Soressi and Geneste [2011]) or the Anglo-American approach of core reduction sequence analysis (Shott 2003), these operational sequences have the potential to more closely approximate the units of cultural learning in CT theory. This is because they include the artisan's choices, which must be made at specific points within the sequence of steps in the production of the assemblage of tools (Riede 2006). Unfortunately, however, even if Paleolithic archaeologists use quantitative and transparent methods for constructing these sequences, which is not always the case (see Bar-Yosef and Van Peer 2009), most tend to assign the detailed sequence from a given assemblage into one of several immutable, essentialized "types" of reduction methods. Alternatively, they invent a new label to add to the long list of existing categorical entities, variously called reduction methods, industrial types, technocomplexes, and technological types (inter alia). It is these categorical entities that are then used as units of analysis for positing a historical narrative of which cultural entities existed, what behaviors they pursued, and where and when they were found in the Pleistocene.

This approach to Paleolithic research continues to obscure the exact behavioral variation we should be studying (Monnier and Missal 2014). The epistemological problem of incomparability between "technological types," much like the proverbial comparison of apples and oranges, eliminates the power of a CT approach when applied to such data (Tostevin 2009, 2011b). John J. Shea (2014) has recently emphasized this same point in his critique of *named archaeological stone tool industries,* or NASTIES, as being obstacles to studying behavioral evolution in this period. I have argued at length that evaluating hypotheses of CT between populations in time and space requires the deconstruction of these generalized categorical types through the recognition within individual artifact assemblages of behavioral units that can be evaluated as potential instances of learning between entities (Tostevin 2007, 2009, 2011b). *If Paleolithic archaeologists are to study culture change in an evolutionarily informed, nonessentialist paradigm,* as is required for studying evolutionary processes and CT (Tschauner 1994), *archaeologists* *need to study this change through time* within *the abstractions we call technocomplexes rather than* between *these typologically defined categories* (sensu Adams and Adams 1991; see also Read 2007).

Yet, even as new categorical types are added to the recognized list of NASTIES, older labels are rarely eliminated from the literature, as Shea (2014) points out. Monnier (2006) has shown how archaeologists' existing views of Paleolithic cultural evolution through time have been influenced more by the inherited history of their research traditions than by newly excavated data (a situation that Wimsatt would recognize as entrenchment; sensu Wimsatt and Griesemer 2007). Indeed, Shea once overheard a senior Paleolithic archaeologist complain (Shea, personal communication, 2014), "We are all prisoners of de Mortillet," referring to Gabriel de Mortillet (1821–1898), the archaeologist who published the first widely used classification of the Paleolithic in 1869. If this applied to the study of the fossil record, current paleontologists would be constrained to use the same immutable units of analysis as those of Georges Cuvier (1769–1832), the founder of comparative anatomy. Instead of being able to utilize the pattern of Retzius lines in the microstructure of dental enamel to understand different developmental growth rates between taxa (Smith et al. 2007), modern paleontologists would be constrained to discussing taxa only in terms of their pointy versus flat canines.

Materiality and Structure in Current CT Literature

The second obstacle confronted by those trying to unite Paleolithic archaeology with cultural evolutionary theory is that current CT models tend to ignore the materiality of the process, such that many Paleolithic archaeologists find the models unsuitable to the material culture they study. Specifically, archaeologists who study artifactual manufacturing sequences, particularly behavioral archaeologists who specialize "in the concrete interactions that take place in the activities constituting the life histories of artifacts and people" (Schiffer and Skibo 1997, 28), have long recognized that to learn how to make an item of material culture is to learn two different and highly structured bodies of knowledge: (1) knowing what you *should* do in the conceptual sense, the *connaissance* of the behavioral gesture in the parlance of the French *chaîne opératoire* school (Pelegrin 1990); and (2) knowing *how* to do it as a bodily action, through the development of the patterned neural connections that enable the correct choice of bodily gesture to be enacted in the correct way—that is, the savoir faire. This is a specific type of developmental structure in the CT process that is lacking in the current literature. Thus, it is not a general lack of attention to how structured content or structured populations affect the results of CT that makes current research less attractive to archaeologists. In fact, compared to the origins of CT research (Cavalli-Sforza and Feldman 1981; Boyd and Richerson 1985), recent studies have contributed significantly to exposing how structure plays out during CT. For instance, CT studies have recently incorporated structural elements such as changes in skillfulness through time (Andersson 2013; Andersson, Törnberg, and Törnberg. 2014; Andersson and Read 2016), the effect of prerequisites within sequentially structured knowledge (Mesoudi and O'Brien 2008; Madsen and Lipo 2015), the costs of acquisition of new knowledge (Mesoudi 2011), and the ramifications on cultural variability resulting from how transmission occurs on a spatial scale (Premo and Kuhn 2010; Perreault and Brantingham 2010; Premo and Scholnick 2011; Premo 2012b; Premo 2015; Premo and Tostevin 2016). Instead, what is lacking in the current approach to CT research is a focus on how the differences in learning these two bodies of knowledge would make the structure of the CT process itself dependent upon the physical realities of each material culture medium. In other words, an archaeologically applicable CT approach needs to model how the results of the transmission can be altered by differences in the material requirements of learning one content versus another—that is, learning an idea versus learning the bodily performance involved in the manufacturing techniques for a specific artifact. This is where closer collaboration with archaeologists can help.

An illustration will help clarify this issue. Boyd and Richerson (2000) artfully point out how the inherent variability in CT units is one of several factors that make cultural evolutionary processes so distinct from biological evolutionary processes:

> Unlike genes, ideas usually are not passed intact from one person to another. Information in one person's brain generates a behavior, and then someone else tries to infer the information required to do the same thing. Breakdowns in the accurate transmission of ideas can occur because differences in the genes, culture or personal background of two individuals can cause one person to make a wrong assumption about what motivated the other's behavior. (54)

Boyd and Richerson's article pictorially captured this variability in the CT unit in a sketch by Dušan Petričić and serves as an excellent critique of meme theory (Dawkins 1976; Blackmore 2000), which posits that the unit of CT is

Figure 8.1. My update of Boyd and Richerson's (2000, Figure 1) classic portrayal of the CT process: "IDEAS often mutate as they pass from one person to another." Inspired by Dušan Petričić's original sketch for *Scientific American* of a letter *A* morphing as it is handed off between three individuals, I have turned the letter into a word to indicate more clearly how the unit of transmission changes as the context of its material expression changes. Here the word *At* represents the preposition, indicating the location where an individual wants to be found for future correspondence. Thus, moving from left to right, an individual hands a large handwritten word, *At* (as one would sign a personal letter for hand delivery: Miss Jane Marple, At the Vicerage, St. Mary Mead), to another figure, who then hands a Courier-font *At* (as on a typewriter-addressed envelope) to the next figure, who passes on an @ sign (as part of an address for computer-based email, jmarple @AgathaChristie.com) to another figure with a Facebook icon, an indication of a one-to-many communication, where one individual can post multimedia to many people via smartphone and social media apps. Illustration by G. B. Tostevin.

in fact gene-like. I have redrawn their concept in an updated form in the present Figure 8.1. The transmitted unit is reshaped, both cognitively and behaviorally, by the process through which it is learned. While this makes the necessary point against any straightforward view of memes, it does not go far enough. How physical requirements for the ideas being transmitted influence the possible variation in how far the ideas can morph between role model and learner is still relegated to the background. In the metaphor of Figure 8.1, CT research needs to start to explore how the shape and slipperiness of the pliable letter (the content) changes how each individual in the process needs to grip, squeeze, and manhandle it between hand offs, with subtle changes in how the letter is distorted in each case. Some letter shapes are easier to hand off without distorting their lines; others require a harder grip that more substantially changes the shape.

Consider the behavioral choices within the operational sequence for how to make a stone tool. These learned choices are not simply susceptible to conceptual misunderstanding in the mind of the learner, akin to simple "cognitive mutation." As hinted at above, these choices have to be learned at *two* levels: the connaissance of the behavioral gesture and the savoir faire to successfully execute the gesture. The savoir faire of flintknapping is extremely specific. It requires the control of thousands of timed muscular contractions to deliver a successful blow of the stone hammer to strike a flake off a core. The motion of the arm delivering the blow occurs in less than a second and can rarely be altered after it has begun. Once the hammer stone touches the core (at a rate of approximately 2.4 meters per second), the rate of fracture propagation separates the flake from the core at a speed of 630–1100 meters per second, depending on the hardness of the stone (Cotterell and Kamminga 1987, 680). In neither the delivery of the blow nor the physics of its result is there time for a knapper to think about the delivery or the consequences of the action. Depending on the physical requirements of learning both the connaissance and savoir faire of each unit of transmission (i.e., a combination of the appropriate choice and appropriate enactment of the choice), there could be *more or less* fidelity in transmission between what is demonstrated and what is learned. Tostevin (2012, chapter 4) provides a conceptual model for how the variables known to control the flake-by-flake knapping process can be altered (i.e., can experience cultural mutation) between the demonstrator and the learner in a simple observation of a flintknapping event. In addition to the variation caused by the two-part learning process, we also know that perception errors resulting from limits on human visual acuity relative to the size of the material being copied contribute to variation in transmission (Eerkens and Bettinger 2001; Eerkens and Lipo 2005; Kempe, Lycett, and Mesoudi 2012). Whether a technology is additive (as in adding clay to a pot during its production) or reductive (removing stone flakes from a core or wood from a carving) also affects the transmission process (Skibo and Feinman 1998; Schillinger, Mesoudi, and Lycett 2014). *The materiality of the content matters and fundamentally changes the process.* This requires us to pay attention to where and how fidelity variation is created in the learning of even the earliest action of material culture creation in the archaeological record, the striking off of one flake from a core.

Lithic technology is not the only material culture whose transmission structure is affected by the physicality of its content. Mark Bedau's (see chapter 6) analysis of inheritance and adaptive radiations in U.S. patents is a perfect and far more recent example of how the physicality of the transmission event changes the pattern of the cultural evolution of technology. The U.S. Patent and Trademark Office (USPTO) requires inventors to cite in their applications all applicable prior patents as the basis for its evaluation of the sufficient novelty in a given application to warrant approval by the USPTO. This physical requirement in the application process makes multiparental inheritance explicit and helps to define the shape of a new technology. In the context of designing an innovation with a mind to patenting it, innovators must not only contextualize what elements they are inheriting but also distinguish their creations from these antecedent patents more than they might otherwise have done. "An important scaffold for the evolution of technology is the inheritance (citation) network among inventions, and content flow in the network is strongly affected by the network's multiparental structure" (see chapter 6). This context contributes a structure of descent with modification to the process that is more explicit than in most processes of cultural transmission and makes patents the best example of a transmitted unit akin to memes yet demonstrated. Patents, and their design elements, are excellent examples of *transmissible elements* (see chapter 1), and this is because of the physicality of the application requirements in the approval process. Because of the more obvious transmissible element, Bedau has been able to demonstrate fascinating cultural evolutionary patterns, including pivotal "door-opening" innovations, within this data set. For Paleolithic archaeologists, to recognize similar cultural evolutionary patterns (or at least to construct data that articulates with cultural evolutionary questions), we need to recognize units of analysis that are equivalent to transmissible elements within the process of learning how to flintknap. This is where material culture began and where we must start if we are to understand what CT processes were utilized by the first hominin populations exploiting cumulative CT.

BRIDGING THE OBSTACLES TO A MORE MEANINGFUL CONTRIBUTION OF PALEOLITHIC ARCHAEOLOGY TO CULTURAL EVOLUTIONARY THEORY

The Need for Comparability within Paleolithic Data for Contributing to CT Theory

The first obstacle—the absence of a connection between the structure of Paleolithic data and the cultural learning sets needed in CT theory—is surmountable if Paleolithic archaeologists choose to analyze the record with more attention to how those analyses will be used for answering specific questions. Specifically, methodological approaches that do not produce an analytical structure that allows the evaluation of predictions from high-level theory should be rejected despite being sanctified by long historical use in the discipline (Tostevin 2011a). Here I am relying on a typology of archaeological method and theory as manifested at three levels of operation: low-level, middle-level, and high-level theory (Thomas 1998, 66–94). Low-level theories include observations obtained in archaeological fieldwork, such as the products of measurement techniques, inferences from the qualitative examination of artifacts, statistical representations of counts and attributes, and published artifact illustrations. Low-level theory is thus "data," the beginning of the archaeological method. Philosophers of science might call this the theory-conditioning of data (William Wimsatt, personal communication). Middle-level theories (or middle range; sensu Binford 1977) connect these observations of the archaeological record to patterns of human behavior. Connections are established through experimental archaeology, ethnoarchaeology, and other types of research designed to recognize causal relationships between the processes of human behavior and their resultant effect on the formation of the archaeological record. High-level theories provide the context for what archaeologists are interested in examining as a research target. They provide the intellectual goals related to asking certain questions of the archaeological record, usually from a specific orientation to explaining the past. Thomas's three-level distinction in method and theory forces us to consider each step of argumentation between the data and the research question. "The three-level distinction allows one to understand how low- and middle-level theories need to be shaped in a particular way in order to achieve the goals of high-level theory" (Tostevin 2011a, 294).

The present high-level theory goals of most Paleolithic archaeologists working on the reconstruction of operational sequences from lithic data are not *inappropriate* goals, but they tend not to produce low-level theory (data) commensurate with other desirable high-level theory goals. This is because most Paleolithic archaeologists strive for *more detail and more richness* in their reconstructions of operational sequences. This leads them to produce "data" that is so specific as not to be comparable in any fashion between contexts, such as different sites.

> In contrast to most other disciplines, archaeology does not aim to reduce a wealth of data to a few essentials. It does the reverse, putting flesh and clothing on "bare bones." Its logic is therefore very different from the logic of the natural sciences, but also from that of the social sciences. (Van der Leeuw 2004, 118)

Paleolithic archaeologists' logic is not unscientific, however, despite Van der Leeuw's observation, but rather aimed at maximizing what can be learned from each specific case of "putting flesh and clothing on the 'bare bones.'"

In particular circumstances, this approach can produce remarkable results. For instance, in Pigeot's (1987, 1990) reconstructions of the flintknapping that took place at Etiolles, a Magdalenian campsite in the Paris Basin, she was able to reconstruct where a master knapper sat demonstrating her/his knapping while surrounded by knappers early in their learning process. This is a rare but convincing argument for the presence of apprenticeship eighteen thousand years ago; an astounding demonstration of an actual CT scaffold in a Stone Age site. Yet it was not data analysis beyond the artifacts of this one site that allowed this result but the astonishing preservation of artifact contexts within the site, particularly the intra-site comparison of reduction sequences that showed execution errors with those that were flawless. In fact, while there is value in the astounding detail of the best reconstructions of operational sequences of lithic technology (Pigeot 1987; Cattin 2002; Bullinger, Leesch, and Plumettaz 2006), pyrotechnology (Plumettaz 2007), and organic technology (Knecht 1993) produced by my Paleolithic colleagues, these studies do not do enough to advance the collaborations that are needed to answer questions about the evolution of CT structures. Because such Pompeii-premise sites are so rare, we cannot move forward with an archaeology of pedagogy without comparable data beyond these well-fleshed-out snapshots.

Endeavoring to articulate low- and middle-level theory with my high-level theory goals of studying CT through Pleistocene archaeological data, I have developed an analytical method for replacing the categorical entities (technocomplexes, reduction methods, industrial types, and other NASTIES) in lithic research with quantitative, behavior-by-behavior reconstructions of assemblage-wide lithic operational sequences that allow comparisons of similarity and dissimilarity between assemblages (Tostevin 2000, 2003a, 2003b; Tostevin and Škrdla 2006). This approach goes a long way to solving both the deceptive emphasis on rare artifacts and the apples-versus-oranges problem of NASTIES in Paleolithic research.

The second obstacle—the need to recognize the creation of structure in the CT process as a result of the materiality of the unit being transmitted—requires an even more drastic reconfiguration of traditional Paleolithic analytical methods. In response to this need, I have proposed an ethnographic-based middle-range theory for predicting which behaviors within a lithic operational sequence are learnable in different contexts of contact between foragers of different social intimacy (Tostevin 2007, 2012). The strategy is to let the CT process itself determine the units of analysis. This is equivalent to taking an evolutionary developmental approach to CT archaeology. How does the observer learn the behavioral details of a lithic operational sequence by watching the performance of a knapper? The physicality of the observational context by which the connaissance is learned, as well as the subsequent repetitions/practice on the part of the learner by which the savoir faire is mastered, determine the structure of the CT process. It is this level of the materiality of the process, which is currently lacking in the literature within CT theory, that makes the unification of Paleolithic archaeology with CT research difficult.

Solving this second obstacle involves archaeologists examining the variables that we know control the shape of each flake as it is removed from the core, the same variables that the observer saw and learned through his own replication within the social intimacy of the group's enculturating environment. This approach goes a long way toward overcoming the obstacle of incorporating CT research into the archaeology of human evolution, regardless of whether it is focused on lithic technology or another material culture. With the help of John Shea's talent for acronyms, I have dubbed this the *behavioral approach to cultural transmission* (BACT).

The Behavioral Approach to Cultural Transmission

BACT considers two sets of questions as a means to structuring lithic analysis to articulate with cultural evolutionary theory. First, *How does dual inheritance occur on the landscape in foraging societies?* This question can be decomposed into more detailed questions: *Where and when are foragers enculturated? Where, how, and when do they witness technological performances that affect their adoption of technological choices, and how do their observations and the feedback they receive in training affect their own performances?* I have endeavored to answer these questions through the construction of a middle-range theory built on ethnographic data (Wiessner 1982, 1983, 1984; Lee and DeVore 1976; Kelly 1995) and anthropological theory (Carr 1995; Wobst 1977; Sackett 1990) directed at understanding how, where, and when individual foragers learn and transmit their cultural behavior (Tostevin 2007, 2009, 2012). Tostevin (2007) presents the kernel of the middle-range theory for predicting which aspects of a lithic operational sequence reflect behaviors that are learned and learnable only in contexts of social intimacy among foragers. Tostevin (2012) develops these ideas in greater detail within the context of an evolutionary approach to Pleistocene CT, building off of dual-inheritance modeling within CT theory (Boyd and Richerson 1985, 1987, 1996; Cavalli-Sforza and Feldman 1981; Richerson and Boyd 1978, 2002, 2005).

Taking a behavioral approach (Schiffer 1975, 1976, 1996) to flintknapping, an artifact assemblage is recognized as the central tendencies and dispersions in flake attributes reflecting specific decisions a knapper must make during the reduction of a core for flake blanks, which are subsequently made into tools to be used on the landscape. These decision nodes, which must be learned over the years of the enculturation of the individual as a skilled knapper, must be taken regardless of the option used at a given node in a given assemblage, making them consistently comparable units of analysis across space and time. Thus, the decision nodes can be treated as cultural instruction sets that would have been visible and thus learnable by foragers present at the different site localities being compared. The exposure of socially intimate individuals to flintknapping performances at base camps and raw-material procurement sites, where enculturation occurs, would have allowed these individuals to witness and learn the body techniques and behavioral details involved in flake production. The social intimacy between the observer and the performer would have afforded the observer the chance not only to learn the connaissance of the behavioral details but, given enough time, to develop the savoir faire of the body techniques. This exposure differs from that of socially distant individuals who would be exposed to the mobile tool kit only, the products of the end of the operational sequence. Because the artifacts of the mobile tool kit are carried onto the pathways of the landscape (Gamble 1999, 68–71), these tools become more visible to socially distant individuals but visible only from "bow-shot" range, the likely range for contact between strange foragers (Wiessner 1983). Given the equifinality in lithic reduction, exposure to mobile tool kits on pathways of the landscape or from discarded tools at retooling camps would not be sufficient for a stranger to produce the same debitage-wide central tendencies for all of the behaviors in the process, even if a few of the options were intuited from a curated tool. Independent innovation or convergence of behaviors within flake production, representing homoplasy, is thus always a possibility but not a high probability. This is the basis of the *taskscape visibility* concept, defined as the relationship between where, when, and with whom a cultural trait, such as a flintknapping behavior, is performed and the possible CT modes (sensu Boyd and Richerson 1985) available for promulgating the trait into the next generation.

Derived as it was from archaeological and ethnographic method and theory alone, Premo and Tostevin (2016) set out to evaluate the taskscape visibility concept using a formal, spatially explicit, agent-based model. Using an established model for the transmission of cultural traits among central-place foragers (Premo 2012a, 2012b), the simulation evaluated the equilibrium diversity of two selectively neutral traits that differed only in their taskscape visibility—that is, where they were learnable on the landscape. The simulation showed that the trait with the lower visibility, which was learnable only at residential base camps, had higher equilibrium diversity levels than the trait with the higher visibility, which was learnable at both base camps and logistical foray camps. Without the recognition of the role of taskscape visibility, which was the only difference between the traits, the difference in the observed equilibrium diversity levels of the two traits might have been incorrectly interpreted as resulting from qualitatively different forms of biased cultural transmission. These results suggest that the theoretical principles derived by archaeologists such as Sackett (1990), Carr (1995), and Wobst (1997) should be incorporated more closely into future CT research.

While the first set of questions addressed by BACT revolves around where interactions of different levels of social intimacy occur on the taskscape, the second set of questions focuses on the microscale, the observational learning of artisan choices: *Which emic choices of the artisan are visible as etic observations by the learner? Which observations of the learner also are etically observable by the archaeologist?* Anthropology's distinction between emic and etic perspectives may be one of the most important contributions to the development of cultural evolutionary theory. The distinction is most often associated with Marvin Harris (1976) and his cultural materialism agenda in cultural anthropology over the last quarter of the twentieth century. Harris, however, did not invent the terms but co-opted them from Kenneth Pike (1967). Pike coined the term *emic* to refer to the internal rules or logic of a behavior from the perspective of a member of the society that practices that behavior. *Etic,* on the other hand, refers to the external perspective of an anthropologist trying to understand a culture-specific behavior in light of participant observation, as well as comparison with other cultures. Pike constructed these terms from a similar distinction in linguistic anthropology: etic comes from *phonetic* (the possible sounds made by different parts of the human vocal anatomy across all humans) and emic from *phonemic* (the subset of etic sounds that a given culture recognizes as making a difference in meaning or semantics).

Recognizing the emic/etic distinction helps illustrate how the process of learning a physical skill such as flintknapping by visual and auditory observation can structure both the forms of the artifacts produced and the means by which archaeologists reconstruct the behaviors that were both learned and performed in a given society. From controlled experiments in fracture mechanics (Dibble and Pelcin 1995; Pelcin 1997, 1998; Dibble and Rezek 2009; Rezek et al. 2011; Lin et al. 2013), we know that the knapper needs to choose particular physical variables on a core to remove a flake with a set of physical properties.[2] To remove a flake, she needs to decide how much of the convexity on the face of the core she wants to remove for the flake to have the desired shape, such as being pointed or round, long or broad, and so on. She chooses these aspects of the dorsal surface of the core by identifying where on a platform opposite this convexity she will strike. She decides how far into the platform from the edge of the core's dorsal surface to strike (the platform thickness or depth) to determine where the fracture plane will intersect the core. She can choose to remove more volume with a deeper platform thickness or alter the exterior platform angle between the platform and the dorsal surface to achieve the same result, since multiple controlled experiments have shown that external platform angle and platform thickness together predict the mass of the removal. The dorsal convexity, on the other hand, contributes most significantly to giving specific shape to that mass. All of these "choices" can be made consciously before the delivery of the blow but are executed together with the split-second delivery of the strike, a movement that cannot be altered after the brain sends the message for the movement of the arm to begin. In a profound way, these "choices" are determined by the unconscious training of motor–neural pathways developed over years of practice.

From the point of view of the observer learning the process, he can tell roughly where the knapper is gazing but not exactly what platform variables she is choosing *emically*. He can estimate the speed (and thus the force) of the delivery of the strike from the position and gesture of the percussing arm. He also can estimate the angle of attack controlled by the arm and leg supporting the core. However, the knapper has the full-body experience of precisely controlling all of these variables in the split second it takes to deliver the blow and remove the flake. The observer has an etic viewpoint, whereas the knapper has a fuller, emic viewpoint, experiencing the blow from the alpha to the omega of the performance. At best, by watching the knapper and even examining the knapper's products as they are removed from the core, the observer has only an etic appreciation of what the knapper actually did rather than what she may have intended to do (i.e., her emic choice). Thus, he can learn the position of that blow within the sequence of removals he has just witnessed (the strategic knowledge inherent in the *connaissance* of the blow) but not the *tactical, savoir faire* know-how to make those removals himself. He must practice for weeks and months, if not years, to develop a full emic level of skill. Thus, in my use of the emic/etic distinction (Tostevin 2012), archaeologists and prehistoric novice flintknappers have parallel relationships. Archaeologists are by necessity relegated to the etic perspective; we cannot access the minds of prehistoric artisans who have their own emic perspective. *But the prehistoric observer at the beginning, if not the end, of the CT process is also limited to the etic perspective, at least for the savoir faire of the content, even though the observer is part of the enculturating environment of that culture.*

Recognizing the Need for the Connaissance/Savoir Faire and Etic/Emic Perspectives in CT Research

The distinction between the parts of the learning process implied by connaissance and savoir faire requires further elaboration. This dichotomous view of *knowing* in the French language has long played a significant role in the understanding of technological performance, including flintknapping in the Old World (Mauss 1935; Chamoux 1978; Pelegrin 1990; Karlin 1991). Apel (2008, 98) provides a helpful discussion of the topic and unpacks the concepts using the English word *knowledge* for *connaissance* and *know-how* for *savoir faire.*

> Knowledge is an integral part of a recipe for action, it is a form of declarative memory and thus consists of theoretical information only, while know-how is an important part of the teaching framework, especially self-teaching by trial and error, since it is a form of muscle memory that can be acquired only through practice (Apel 2001; Roux and Brill 2006). Pelegrin's terms [*connaissance* and *savoir faire*] have the advantage that they make a sharp distinction between information acquired from a source outside the body and the type of know-how that can only be achieved by coordinating the muscles involved in a gesture.

Connaissance/knowledge is thus learnable to a far greater degree by observation alone (possibly aided by verbal communication), whereas savoir faire/

know-how must be learned by an individual through extensive bodily repetition.

Wynn and Coolidge (2004) also provide a useful discussion of this distinction in relation to the working memory concepts from cognitive science (Baddeley and Logie 1999; Baddeley 2001) and cognitive anthropology literature on the phenomenological acquisition of skill (Keller and Keller 1996). For Wynn and Coolidge, both knowledge and know-how are part of Keller and Keller's blacksmith's "stock of knowledge," as well as part of Ericson and Kintsch's (1995) "long-term working memory" from cognitive psychology, which allows the enactment of complicated tasks with little loss of attention to other behaviors. Wynn and Coolidge's synthesis of these perspectives points to ten years of practice for the acquisition of expert know-how.

Figure 8.2 presents an unpacking of these concepts according to different authors. To these oppositions, I add that savoir faire in flintknapping constitutes the tactical know-how or skill to successfully execute a blow to

Connaissance/Knowledge	**Savoir faire/Know-how**	**Source**
Explaining	Acting	Apel (2008, Table II)
Explicit memory	Unconscious memory	Apel (2008, Table II)
Communicative	Intuitive	Apel (2008, Table II)
Theoretic memory	Muscle memory	Apel (2008, Table II)
Lost in case of conscious memory loss	Not lost in case of conscious memory loss	Apel (2008, Table II)
Semantic	Nonsemantic visual, tactile, and aural imagery	Wynn and Coolidge (2004)
Declarative knowledge	Skill/ability to replay motor behaviors	Wynn and Coolidge (2004)
Concept	Experience	Apel (2008, Table II), modified by Tostevin
Strategic knowledge: the plan for a sequence of removals within core reduction, including contingency plans for error corrections.	*Tactical know-how:* the skill to successfully execute a blow dictated by the strategic plan.	Tostevin (present paper)

Figure 8.2. The unpacking of *connaissance* versus *savoir faire* according to Apel (2008, Table II), Wynn and Coolidge (2004), and the present author.

remove a desired flake. The flake-by-flake variables I described above thus equate to the tactical know-how of savoir faire. Connaissance for flintknapping, on the other hand, constitutes the strategic knowledge or plan for exploiting the core volume down to exhaustion through the removal of a long sequence of flakes. The strategic plan includes the creation of the relationship between core surface convexities, as well as the subsequent rotation of the core for the exploitation of different platforms. Strategic knowledge also includes contingency plans for correcting errors in the ever-changing morphology of the core that could cause its premature discard. Thus, while tactical decisions are enacted with each flake in a reduction, strategic decisions are made at the level of each core reduction.

Given how strategic knowledge must be observed etically to be learned but how tactical know-how must be observed etically and then practiced emically to be learned, the physicality of the transmission process puts the observer and the archaeologist in the same etic perspectives to the transmission event. Thus, for the archaeologist, tactical decisions within an assemblage of stone tools from a given site are characterizable through the central tendencies and dispersions in etically observable variables across the population of flakes in the assemblage, just as they were to the observer as she or he continuously practiced to get products to approximate the morphology of the products of the original performer. The strategic decisions are etically characterizable, on the other hand, at the level of the entire assemblage (or the smallest level of meaningful geoarchaeological association, such as raw material units, e.g., Turq et al. [2013]; Machado et al. [2013, 2016]). The fact that these choices are as observable to the archaeologist through a quantitative attribute analysis (Figure 8.3) as they were to the observer allows archaeologists to avoid the epistemologically dangerous task of guessing the emic logic of the prehistoric knapper, as often happens with teleological reconstructions of operational sequences (Dibble et al. 2017). Instead, BACT for lithic technology allows one to characterize an assemblage in terms of the quantitative choices enacted at different parts of the knapping process that had to be learned etically and then practiced emically in socially intimate contexts. These behavioral choices are thus suitable as transmissible elements for the investigation of cultural evolutionary processes in the archaeological record.

For operational sequences of sufficient complexity, the separation of the material content of the learning process into two levels (tactical know-how vs. strategic knowledge) creates a distinct transmission isolating mechanism

Flintknapping domain	Decision node characterized by archaeological observations	Type of knowledge
Core modification	Core orientation: extant core morphologies	Strategic knowledge
	Core convexity management: refits, diagnostic reparations	Strategic knowledge
Pattern of core rotation during reduction	Early exploitation: dorsal scar patterns of blanks vs. blank length	Strategic knowledge
	Late exploitation: dorsal scar patterns of blanks vs. blank length	Strategic knowledge
Platform maintenance	Platform Treatment	Tactical know-how
	Exterior platform angle	Tactical know-how
	Platform thickness	Tactical know-how
Dorsal surface convexity	Longitudinal extent of the surface removed: length/width ratio	Tactical know-how
	Vertical convexity of the mass removed: width/thickness ratio	Tactical know-how
	Longitudinal shape of the surface: lateral edge type	Tactical know-how
	Dorsal ridge system: number of ridges defining the convexity: cross-section type	Tactical know-how
	Curvature of the core surface removed: profile type	Tactical know-how

Figure 8.3. Archaeologically observable decision nodes in a flintknapping operational sequence according to the type of knowledge implied by the distinction between strategic knowledge (learnable by etic observation of the process) and tactical know-how (learnable to an emic level only through bodily practice). Methods for the measurement and characterization of each decision node are provided in Tostevin (2012, chapter 4).

(TRIM) (Durham 1991; Mesoudi 2011). As Foster and Evans (see chapter 5) emphasize:

> Whenever transmissible units depend on extensive previous training or time-consuming pedagogy for reliable transmission, their spread across populations will be slower and cultural evolution more likely to manifest a branching

> mode on some level of analysis (Boyd et al. 1997; Wimsatt 2013). This should be true whether the transmissible unit is crafting a stone tool or crafting an elegant proof.

I also would add that for Pleistocene hunter–gatherers the cultural evolutionary branching pattern is likely to be symmetric with the branching pattern of biological inheritance for the individuals involved, since emic-level training in foragers does not happen unless the individuals involved are socially intimate enough to be members of the same gene pool (Tostevin 2007).

MODELING THE INTERACTION BETWEEN SCAFFOLDS AND THE CT PROCESS FOR ACQUIRING FLINTKNAPPING SKILL

If the operation of the etic/emic and connaissance/savoir faire structural oppositions in the process of CT for flintknapping creates a TRIM, to what extent can the process vary depending on the support of transmission accelerating mechanisms (TRAMs)? To ask the question another way, how does the support of scaffolds (sensu Wimsatt and Griesemer 2007) affect the acquisition of both types of knowledge? Attempting to answer this question is critical to the development of a robust cultural evolutionary theory, since it will determine how CT content that differs in its material requirements vis à vis strategic versus tactical knowledge affects the role of scaffolds and other evolutionary forces. As scaffolds and other CT structures likely played significant roles in the evolution of human society from the Pleistocene to the Holocene, understanding their roles in even simple technological systems should be useful. For the final section of this chapter, I offer a comparison of a series of conceptual models of the role of scaffolds in the acquisition of flintknapping skill.

Wimsatt and Griesemer (2007) recognize three types of scaffolds, building off of developmental psychology's artifactual metaphor for the role of teachers' and others' behaviors that facilitate a child's development (Greenfield 1984; Bickhard 1992; Lave and Wenger 1991).

1. *Artifact Scaffolding:* "Artifacts can scaffold acts when they make acts possible, feasible, or easier than they otherwise would have been" (Wimsatt and Griesemer 2007, 60).
2. *Infrastructure Scaffolding:* "The most important mode[s] of infrastructural scaffolding are forms without which culture and society would not

be here at all. Going backwards in time: written language, settlements and agriculture, and animal husbandry and trade practices (developing into economic systems) were major infrastructural innovations central to all that followed. Spoken language with oral traditions and tools use antedate all of these by many tens to hundreds of thousand years. All are generatively entrenched so deeply as to be virtually constitutive of all of our forms of life, limiting the kinds of presence-and-absence comparisons we would like to have to assess their effects" (65).

3. *Developmental Agent Scaffolding:* "Scaffolding skills in agents where the scaffold is (or includes) another agent are particularly interesting: the scaffold is or involves another person, social group, or organization, often in spatial and temporally organized dynamical arrangements with artifacts" (66).

In the present case, I take the cognitive capacities of prehistoric actors to be elements of infrastructure scaffolding. Are these scaffolds or prerequisites? It is difficult to say, and thus the distinction between infrastructure and artifact scaffolding is useful. As each of the questions asked in the introduction to this chapter concerning the development of CT structures during the course of human evolution includes one or more of these types of scaffolds, how can we conceive of these scaffolds affecting the fidelity of learning knapping skills?

Figures 8.4–8.9 present scenarios that diagram the gradual development of knapping skills across the duration of the transmission process *(moving from the top of the figure to the bottom)* due to the influence of a "knowledgeable knapper (K)" on a "naïve observer (O)." Scenarios differ based on the action of the different types of scaffolding structures that have been proposed as significant in the evolution of the cumulative capacity for culture (see, e.g., Sterelny 2012). The three types of scaffolds serve as column headings running across the top of the figure and the gradual development of a naïve individual's etic and emic perspectives on the observed/transmitted content runs down the right-hand side of the figure.

Scenario A (Figure 8.4) has the most minimal of scaffolding possible while still giving K some influence on the learning of O. Here, the infrastructure scaffolding consists of O's cognitive capacity for emulative learning—that is, learning the goal but not the step-by-step procedure for an operation (Tomasello 1996). K only serves as a developmental agent scaffold in that her social tolerance of O's presence allows O to learn from K's activities with

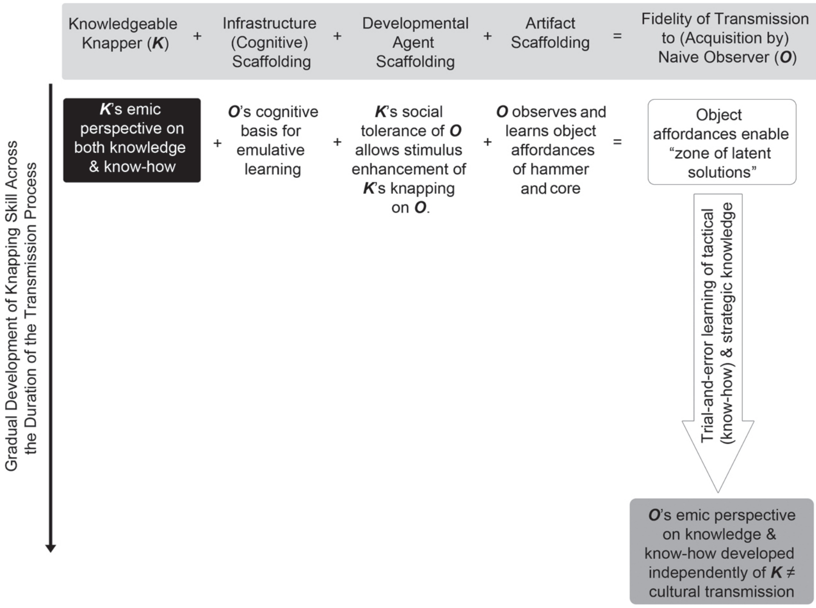

Figure 8.4. Scenario A, emulation learning: A conceptual model for the most minimal of roles for scaffolds in the gradual development of knapping skills by *Naïve Observer (O) (top right)*, due to the influence of a *Knowledgeable Knapper (K) (top left)*. Beginning with K's complete emic perspective on both strategic knowledge and tactical know-how, the column headings at the top of the diagram represent the summation of the infrastructure scaffolding, developmental (agent) scaffolding, and artifactual scaffolding that can contribute to O's learning of K's knowledge. The gradual development of the naïve individual's etic and emic perspectives on the observed content is represented from the beginning to the end of the process as the movement from the top of the figure to the bottom along the arrow in the rightmost column. The fidelity of O's acquisition of K's knowledge is represented by the degree of saturation of the grayscale coloration of the text boxes and arrow, with a fully saturated black coloration equating to complete fidelity between O and K, while a white text box indicates no similarity between O's and K's knowledge. Rows within the middle of the diagram represent that action of scaffolds available in the given scenario. The vertical placement of the rows of scaffolding actions does not imply any sequential order or absolute timing to their actions within the developmental process of O's acquisition of knowledge. It is assumed that the actions of these scaffolds are cumulative both vertically and horizontally across the diagram.

hammer and core, a process known as stimulus enhancement (Charman and Huang 2002; Franz and Matthews 2010; Matthews, Paukner, and Suomi 2010). As a result, O learns the object affordances of the artifacts (artifact scaffolds) and by her own trial-and-error experimental learning acquires strategic knowledge of the utility of making a cutting edge by conchoidal fracture. In this scenario, there is no other feedback between the learning activities of O on the part of K. Thus, Scenario A represents scaffolding that facilitates the *zone of latent solutions* (sensu Tennie, Call, and Tomasello 2009; Tennie et al. 2017) that we see in chimpanzee societies. Whether this scenario applies to the australopiths or early *Homo* remains to be seen. But this scenario serves as the absolute base from which we can enrich the process with more and more scaffolds. In many CT theories, the independent discovery of both knowledge and know-how in this scenario indicates that there was *no* cumulative CT, depending on whether one considers low-fidelity social learning, such as stimulus enhancement, as a mechanism that would lead to cumulative culture (see Tennie et al. [2017] for a diversity of opinions on this question).

Scenario B (Figure 8.5) differs from A because O's cognitive capacity now privileges her focus on sequential behaviors as meaningful to her own behavior. In other words, her infrastructure scaffolding includes imitative learning (Whiten et al. 2009), the learning of not only the goal but the means to achieve it. This change from Scenario A allows O to learn more from K's proximity in that she can learn K's sequence of blows—the strategic knowledge of the process accessible via an etic perspective. The artifact scaffolds also take on a different role in that O's examination of K's core and flakes can serve as models for her own practice knapping, which is still vital because she begins with no know-how. This scenario thus produces a gradual increase in the emic-level learning of O to that of moderate fidelity to that of K and is diagrammed in the scenario through the increase in gradient from white to gray in the arrow on the right of the figure.

Scenario C (Figure 8.6) has both K and O possessing joint attention toward O's learning to knap, another increase in infrastructure scaffolding. Tomasello et al. (2005) refer to this as triadic attention. The joint attention produces a greater involvement of K in O's learning through the social intimacy of K to O and K's active pointing and gestures of direction to O. These interventions of K might include actively taking O's core from her hands to correct an error of platform management by reparation removals before returning the core for O to continue the pursuit of her strategic plan. Ferguson's (2008) experimental work has demonstrated that this is a successful scaffold in increasing the speed of modern humans learning to knap. The social intimacy afforded O now allows her to repeatedly practice in company with K and thus have continuous opportunities to compare body motions, core-holding configurations, and the resultant artifacts between her and K's reductions. This produces a faster acquisition of tactical know-how and

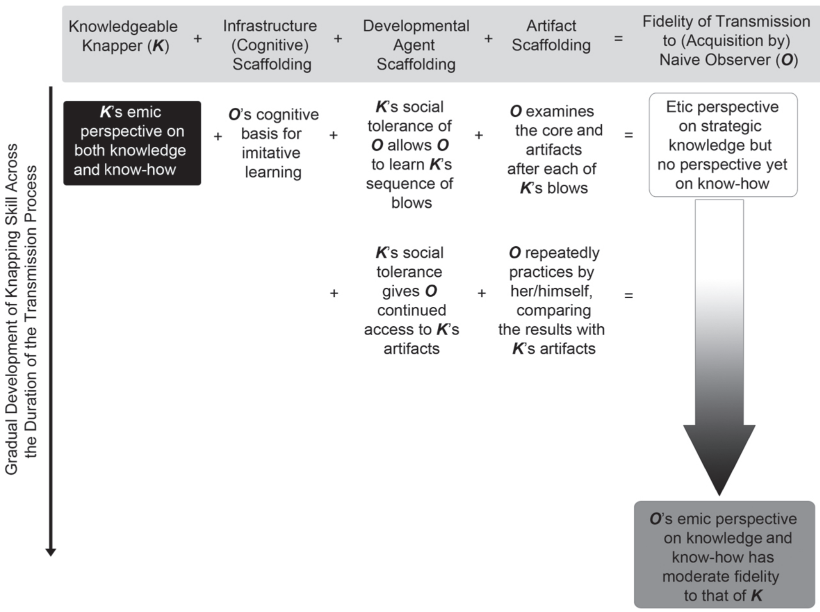

Figure 8.5. Scenario B, imitation learning: A conceptual model for the role of scaffolds in the gradual development of knapping skills by *Naïve Observer (O) (top right)*, due to the influence of a *Knowledgeable Knapper (K) (top left)*. Beginning with K's complete emic perspective on both strategic knowledge and tactical know-how, the column headings at the top of the diagram represent the summation of the infrastructure scaffolding, developmental (agent) scaffolding, and artifactual scaffolding that can contribute to O's learning of K's knowledge. The gradual development of the naïve individual's etic and emic perspectives on the observed content is represented from the beginning to the end of the process as the movement from the top of the figure to the bottom along the arrow in the rightmost column. The fidelity of O's acquisition of K's knowledge is represented by the degree of saturation of the grayscale coloration of the text boxes and arrow, with a fully saturated black coloration equating to complete fidelity between O and K, while a white text box indicates no similarity between O's and K's knowledge. Rows within the middle of the diagram represent that action of scaffolds available in the given scenario. The vertical placement of the rows of scaffolding actions does not imply any sequential order or absolute timing to their actions within the developmental process of O's acquisition of knowledge. It is assumed that the actions of these scaffolds are cumulative both vertically and horizontally across the diagram.

strategic knowledge from the beginning of the process, which results in a high degree of fidelity in transmission. Even when O engages in purely trial-and-error learning on her own, the social intimacy of O and K would produce a feedback loop between K and O based on K's evaluation of O's products.

Scenario D (Figure 8.7) shows K and O sharing linguistic abilities and a common language as the infrastructure scaffolding. K can now actively teach

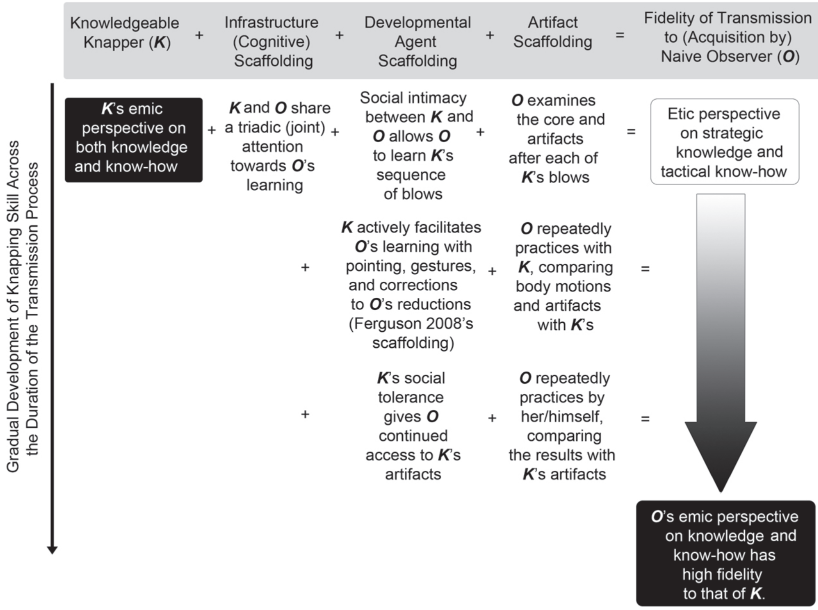

Figure 8.6. Scenario C, triadic attention: A conceptual model for the role of scaffolds in the gradual development of knapping skills by *Naïve Observer (O) (top right)*, due to the influence of a *Knowledgeable Knapper (K) (top left)*. Beginning with K's complete emic perspective on both strategic knowledge and tactical know-how, the column headings at the top of the diagram represent the summation of the infrastructure scaffolding, developmental (agent) scaffolding, and artifactual scaffolding that can contribute to O's learning of K's knowledge. The gradual development of the naïve individual's etic and emic perspectives on the observed content is represented from the beginning to the end of the process as the movement from the top of the figure to the bottom along the arrow in the rightmost column. The fidelity of O's acquisition of K's knowledge is represented by the degree of saturation of the grayscale coloration of the text boxes and arrow, with a fully saturated black coloration equating to complete fidelity between O and K, while a white text box indicates no similarity between O's and K's knowledge. Rows within the middle of the diagram represent that action of scaffolds available in the given scenario. The vertical placement of the rows of scaffolding actions does not imply any sequential order or absolute timing to their actions within the developmental process of O's acquisition of knowledge. It is assumed that the actions of these scaffolds are cumulative both vertically and horizontally across the diagram.

O the emic logic behind the strategy of removals, which might include ritual and superfluous steps to buffer the fidelity of the transmission through *overimitation* (Mace and Jordan 2011; McGuigan 2012). Compared to Scenario C, O can now achieve an emic perspective on strategic knowledge far earlier, and the ability of K to communicate with verbal cues during O's reductions may accelerate the development of tactical know-how, although

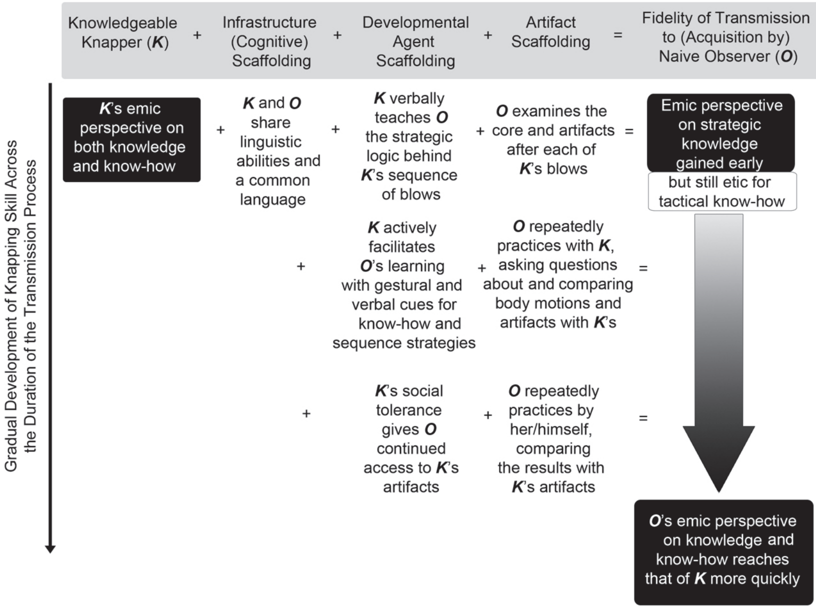

Figure 8.7. Scenario D, linguistic instruction: A conceptual model for the role of scaffolds in the gradual development of knapping skills by *Naïve Observer (O) (top right)*, due to the influence of a *Knowledgeable Knapper (K) (top left)*. Beginning with K's complete emic perspective on both strategic knowledge and tactical know-how, the column headings at the top of the diagram represent the summation of the infrastructure scaffolding, developmental (agent) scaffolding, and artifactual scaffolding that can contribute to O's learning of K's knowledge. The gradual development of the naïve individual's etic and emic perspectives on the observed content is represented from the beginning to the end of the process as the movement from the top of the figure to the bottom along the arrow in the rightmost column. The fidelity of O's acquisition of K's knowledge is represented by the degree of saturation of the grayscale coloration of the text boxes and arrow, with a fully saturated black coloration equating to complete fidelity between O and K, while a white text box indicates no similarity between O's and K's knowledge. Rows within the middle of the diagram represent that action of scaffolds available in the given scenario. The vertical placement of the rows of scaffolding actions does not imply any sequential order or absolute timing to their actions within the developmental process of O's acquisition of knowledge.

verbal communication can only do so much to aid this step. Yet O's emic perspectives on both strategic knowledge and tactical know-how are acquired even faster with this level of scaffolding compared to Scenario C, as is reflected in the darker gradient in the arrow on the right of the figure.

In moving from Scenario A to D, we can see how the different scaffolds can actually change the mode of transmission (sensu Boyd and Richerson 1985) of flintknapping skill. Scenario A can be characterized as predominantly guided variation, with the inheritance of the kernel of a concept, in this case the affordance of hammer and core to make a sharp flake, supplemented by O's trial-and-error learning. With Scenario D, the mode has become a form of biased transmission with less reliance on trial-and-error learning. While the observer still needs repetitive practice to approach K's emic skill level, the movement from etic to emic skill is faster, and thus the source of the biased transmission is more favored than the individual's trial-and-error learning. This would have the effect of increasing during transmission the coherence of design recipes, the fidelity of elements within behavioral packages, and the resultant covariation of variables measurable by archaeologists. *Recognizing the role of scaffolds in changing the mode of transmission thus has repercussions for how archaeologists and cultural evolution modelers think about what "modes" mean.* Bettinger and Eerkens's (1999) influential analysis of the adoption of bow-and-arrow projectile technology over that of spear-thrower technology in the American Great Basin at 1,350 years before the present used the absence of covariation in measurements associated with arrowhead design as being a result of guided variation in the transmission of Eastern Californian arrowhead knowledge compared to the strong covariation between these elements in Central Nevada, which was argued to be the result of indirect bias transmission. Rethinking Bettinger and Eerkens's argument, we can understand this difference in terms of the action of different developmental agent scaffolds related to social intimacy during transmission in each regional context. This observation removes much of the sting in Bamforth and Finlay's (2008) strong critique of Bettinger and Eerkens's assumptions about the meaning of variance in stone tool attributes. Citing the experimental work of Ferguson (2008), Bamforth and Finlay point out that large versus small variance in a given measurement can indicate different degrees of skill, not mode of transmission. But recognizing that the different modes of transmission in fact represent the effects of *different scaffolds for learning skill,* we can see that Bettinger and Eerkens and Bamforth and Finlay are arguing from two sides of the same coin.

This approach to modeling the role of scaffolds of different types in the fidelity (and even ability, given Scenario A) of CT can also be used to diagram other complex scenarios of "learning." For instance, Figure 8.8 presents a diagram depicting the scaffolds available during an episode of stimulus diffusion (Kroeber 1940)—that is, the transmission process in which the context of contact limits the transmission between individuals to only the idea of an object but not its techniques of production. Under the taskscape visibility concept for lithic technology, a stimulus diffusion scenario depicts the transmission of the idea of a tool, such as its morphology, to a Stranger (S) without the transmission of the detailed, specific knowledge to produce the morphology within the original enculturating environment exemplified by K's knapping. This process would occur when a socially distant individual gains access only to the limited results of K's flintknapping, either when S encounters K's discarded mobile tool kit when K is not present or when S encounters K with her tool kit at a logistical foray camp where the core reduction that produced the tool kit is not pursued (Tostevin 2007). In this scenario, however, S is an expert flintknapper, with both the strategic knowledge and tactical know-how of her own group, but she is unfamiliar with the material culture of K's enculturating group. S's task in this scenario is thus not to develop tactical know-how but to acquire K's strategic knowledge.

Recently, there has been some theoretical discussion of the role of lithic artifacts from preceding periods being, for all intents and purposes, artifact scaffolds for the reinvention of lost methods by artisans in later periods. Hiscock (2014) raises this possibility, even going so far as to describe the persistence of lithic artifacts on the landscape surface for millennia as a "library of stone" from which later knappers will learn. Such unburied artifacts on the landscape would certainly be sources of stimulus diffusion, and there is artifactual evidence that much older artifacts served as blanks for subsequent reshaping into new tools in later periods, such as Middle Paleolithic artifacts serving as blanks for tools made during the Upper Paleolithic (Belfer-Cohen and Bar-Yosef 2015). Yet beyond artifact reuse, the results of transmission under Hiscock's hypothesis would be limited to stimulus diffusion by the effect of equifinality, the archaeological observation that there are multiple ways to reduce a core (by the application of different bodies of strategic knowledge) that will produce similar flake morphologies (e.g., Boëda 1995, Figure 4.13). When S encounters K's object without K's performance, there is no guarantee that S will be able to reverse engineer K's original strategic knowledge from the old object's morphology. Being a skilled knapper herself, however, S would likely be able to reengineer the strategic technology to a generic level, perhaps equivalent to the largest recognized units of global variability in stone tools, Shea's (2013) modes A–I. Upon encountering a blade of particular dimensions, for instance, S would be able to recreate a blade technology of those dimensions but likely not the specific variety of blade technology (pyramidal vs. *semitournant*, bidirectional vs. unidirectional, etc.). Given equifinality, the exact reverse engineering of the details

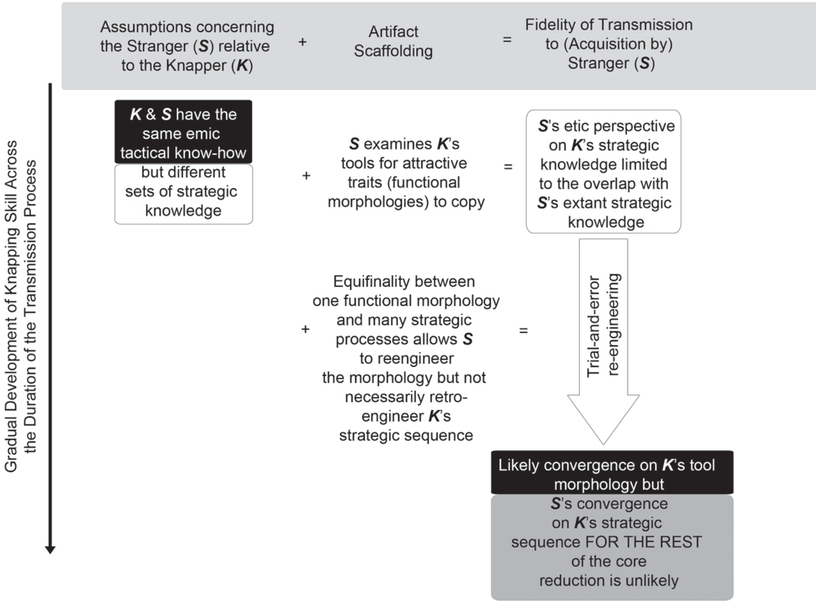

Figure 8.8. Conceptual modeling of the scaffolding available to an expert knapper during the stimulus diffusion (sensu Kroeber 1940) of the morphology of a lithic tool transported to a location where the early part of the operational sequence is not pursued. The diagram depicts the accurate transmission of the idea of the tool to *Stranger* (*S*), with S's independent trial-and-error learning to reengineer the core reduction details to produce the tool morphology. The likelihood of the reengineering as retro-engineering that would match K's original strategic knowledge depends on the breadth of equifinality between the multiple pathways of strategic knowledge that lead to that tool form and S's ingenuity and willingness to invest time in accuracy beyond simply achieving the morphology. The point of this conceptual model is to diagram the limited number of scaffolds available to the expert prehistoric knapper beyond her own emic levels of strategic and tactical knowledge.

of platform thickness, exterior platform angle, core rotation patterns, reparation techniques, and so on of K's knowledge seems unlikely. It is possible but the lack of scaffolds for S's reverse engineering, compared to the scaffolds afforded O in Scenarios B–D, makes stimulus diffusion more likely than diffusion of both the strategic plan and the final tool morphology.

My argument for the likelihood of stimulus diffusion over full transmission in such a case is quantitative only in comparing the count of available scaffolds between Figures 8.4–8.7 and Figure 8.8. In representing the strength of each scaffold, I can only be qualitative, as this subject has simply not been the focus of adequate quantitative experimental research. Therefore, I speak only of likelihoods and not exact probabilities. Further, I am extremely

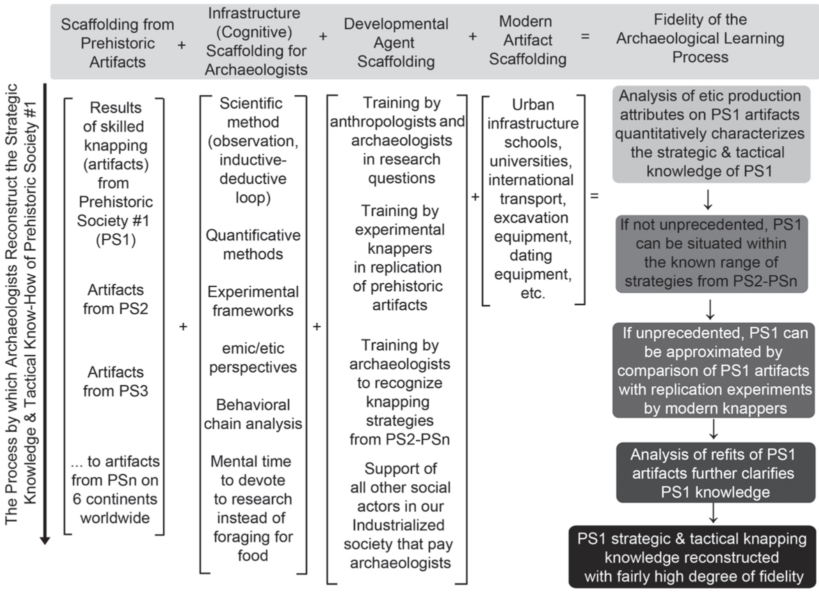

Figure 8.9. Conceptual modeling of the scaffolding available to professional archaeologists for learning (reconstructing) the strategic knowledge and tactical know-how of stone tool artisans from a specific prehistoric society. The types of scaffolding available are listed at the top of the diagram as column headings, starting at the top left with prehistoric artifacts of many societies, beginning with prehistoric society #1, the target for the present reconstruction, but also including reference training sets of artifacts from prehistoric society #2, #3, and so on, through to prehistoric society #n. As the number of scaffolds within each type are too numerous and interdependent to link from left to right, the effects of the scaffolds are depicted within each scaffold type as a matrix set. The matrix sets are summed to contribute to the archaeological learning processes in the rightmost column.

conscious of the wisdom of John Shea's observation that "time and again, the stone tool evidence shows that the surest way to be wrong in human origins research is to under-estimate Pleistocene hominins' behavioral variability" (Shea 2017, 191). Yet one of the reasons for my willingness to risk running afoul of his warning is the difficulty we archaeologists ourselves face in attempting to accomplish a similar task. This point can be illustrated by examining what is required in terms of scaffolds of all three types for the reverse engineering of a prehistoric technology within the contexts of an industrially supported archaeological community. In Figure 8.9, the left-hand axis now depicts the process by which archaeologists reconstruct the strategic knowledge and tactical know-how of a specific prehistoric society (in this case, prehistoric society #1, or PS1). The required scaffolds are now so numerous within each type that the individual scaffolds are presented within matrix sets so that the vertical axis only applies to the rightmost column in which the fidelity of the archaeological learning process is given. As with the stimulus diffusion scenario, note the absence of prehistoric artisans themselves in the diagram.

In constructing Figure 8.9, I was forced to recognize more developmental agent scaffolds in my own training than I am used to, which was a humbling process. Even so, the diagram is perhaps overly optimistic about the accuracy of archaeological reconstructions. The archaeological learning processes begin at the top of the rightmost column and gradually darken as they approach complete accuracy in reconstructing the prehistoric methods by the bottom of the rightmost column. This is certainly an idealized situation if not a pipe dream, for, apart from a dozen truly expert knappers worldwide, most lithic analysts do not possess within themselves the tactical know-how to match the best prehistoric artisans, particularly from periods in which lithic craft specialization was an occupation. Where archaeologists have an edge is their greater breadth of strategic knowledge gained from the examination of artifact collections from the Pliocene to the modern period from all six prehistorically occupied continents. In other words, while most archaeologists are not as tactically skilled as the knappers in the past, their purview on strategic knowledge is far greater. We are trained to recognize all of Shea's modes A–I, whereas most prehistoric societies practiced only a subset of these modes. Thus, an archaeologist has the advantage in retroengineering a specific strategic knowledge set, whereas an expert knapper engaged in a prehistoric stimulus diffusion scenario would have an advantage, and thus a tendency, to prioritize effective reengineering given her extant and more limited strategic knowledge.

RECENT EXPERIMENTAL INVESTIGATION OF SCAFFOLDING AND MUTATION RATES IN THE LEARNING OF LITHIC TECHNOLOGY

I have endeavored to convey the complexity of the scaffolds necessary even for an archaeologist, with all of our industrial support, to replicate a technology represented by the complex interplay between tactical knowledge held in body memory and strategic knowledge held in conscious memory. This complexity puts the lie to Gould's (1987, 70) often quoted characterization of CT as "five minutes with a wheel, a snowshoe, a bobbin, or a bow and arrow may allow an artisan of one culture to capture a major achievement of another." Even giving Gould the benefit of the doubt in assuming that his scenario represents stimulus diffusion rather than the transmission of both true strategic knowledge and tactical know-how, I would not bet on the success of his bow and arrow. With only five minutes of learning, he would likely starve.

Unfortunately, Gould is not alone in misrepresenting the prehistoric learning process. Other scientists, including archaeologists, at times ignore the importance of the dual nature of learning bodily performances when conducting controlled experiments on learning. Morgan et al. (2015) have recently published an experimental study in which 184 individuals were trained in flintknapping under five varying parameters of transmission. The parameters included *reverse engineering* in which the naïve observer was given a hammer stone and a core and shown stone tools but never a knapper in action (akin to the stimulus diffusion scenario above, save that their knappers were completely naïve); *imitation/emulation* (equivalent to Scenario B above); *basic teaching* in which the demonstrator could alter the grip of the learner on the core and slow his own demonstrations but not use gestures beyond these (more limited than the scaffolding presented in Scenario C above); *gestural teaching* (fully equivalent to Scenario C above); and *verbal teaching* (equivalent to Scenario D above). What is striking in the experimental structure of Morgan et al.'s study is first, the large sample size of learners, articulated into transmission chains of learners teaching learners in iterations of five to ten "generations." For the first time, a knapping experiment has achieved a sufficient sample size of learners to produce statistically analyzable results. Second, the similarities between Morgan et al.'s five *transmission mechanisms* and the scaffolding scenarios above (B, C, D, and stimulus diffusion) show a clear convergence in how scholars are conceiving of the additive nature of learning mechanisms since my conceptual modeling above was independently created before the publication of Morgan et al.'s study. Admittedly, Morgan et al. do not mention "scaffolding" or similar structural relationships within the physical constraints within lithic cultural transmission, but the overall intent is similar. Further, Morgan et al. usefully compare their results to the question of how hard different prehistoric technologies were to learn with different mechanisms. Overall, they concluded that for most of their measures only verbal teaching consistently produced a positive effect on learning, and thus lithic technology more complex than

Oldowan reduction, which their experiment replicated, likely required verbal instruction in the past.

What is markedly different between our views of the learning process, however, is Morgan et al.'s ignorance, given how they structured their experiment, of the importance of bodily practice in the acquisition of both strategic knowledge and tactical know-how. *Ironically, like Gould, they fixed on a five-minute educational window.* Each learner was only exposed to the learning environment for five minutes before being required to teach the next generation. As a result, the learners situated later in the transmission chains performed more and more poorly, until by generation five the learners in the verbal teaching cohort were performing as poorly as those in the reverse engineering and imitation/emulation groups, which possessed the fewest scaffolds. *The results in fact demonstrated that the quality and efficacy of CT declined through time within the experiment. There was in fact little to no preservation of learned behaviors between generations beyond what observation alone could accomplish.* Contrary to the authors' conclusions, the only evidence for maintenance of skill and possibly a ratchet effect—that is, improvement in knapping skill between generations one and five—were the reverse engineering and imitation/emulation groups that showed a very slight increase in the proportion of viable flakes produced, although below the level of statistical significance (Morgan et al. 2015, Figure 2h). My hypothesis in this case is that learners in these latter two groups were allowed to focus more on their own trial-and-error learning of tactical know-how without the interruption of less than accurate scaffolding attempts by the increasingly inept teachers found in the later generations of the cohorts of the "more complex" mechanisms. It is laudable that Morgan et al. documented the decline in both the frequency and accuracy of the verbal communications by instructors across the transmission chains, although they did not contextualize the breadth of knowledge or length of teaching experience of the initial trained experimenters at the beginning of each transmission chain, issues that are relevant to teaching lithic technology (Bamforth and Finlay 2008; Shea 2015). In summary, their experiment only modeled the transmission of strategic knowledge, as it did not allow enough time for the development of any tactical know-how, although the measures used to assess the success of the transmission were directly related to tactical skill, not strategic skill.

Despite these limitations, however, the scope of the Morgan et al. study across these mechanisms and across such numbers of learners sets a new bar for experimental work in this area. If the study were repeated with sufficiently long periods of instruction to achieve a stable CT environment, much could be learned from this type of experiment. The decision on what constitutes a sufficient length of instructional time, regardless of which mechanism is being used, could be informed by flintknappers who have taught these technologies in practice. Shea (2015), who has taught flintknapping for over three decades, argues for at least one hour of instructor time to teach Acheulean handaxes and three to six hours for hierarchical cores such as Levallois or blade technology. From my experience teaching a flintknapping course of twelve students once a year for fifteen years, the necessary time for student practice *after* this initial exposure can be as much as double the instructional time.

Morgan et al. (2015) are not alone in ignoring the role of savoir faire learning in a CT experiment related to flintknapping. As Lycett et al. (2015) summarize, their research team conducted two experiments designed to evaluate the effects of size mutation (Kempe, Lycett, and Mesoudi 2012) and shape mutation (Schillinger, Mesoudi, and Lycett 2014) in the copying of an Acheulean handaxe. In the first study, naïve participants were asked to use a tablet computer's touch screen to resize an image of an Acheulean handaxe to that of an example image. In the latter experiment, participants were asked to use a stainless steel table knife to carve the shape of a model Acheulean handaxe out of a standardized plasticine block. While each experiment was well executed and in its way ingenious, as was their overall purpose in creating a "model organism" context to stimulate CT research (Lycett et al. 2015), neither experiment made any effort to approximate the material reality of the process involved in acquiring or utilizing the savoir faire of flintknapping. Studying the effects of size mutation (Kempe, Lycett, and Mesoudi 2012) might arguably be a question of connaissance, but surely the rate of shape mutation (Schillinger, Mesoudi, and Lycett 2014) relies upon the fidelity of the transmission of savoir faire far more than connaissance and so should not be removed from the experiment. The results of both studies are thus highly suspect if they are to be applicable to the knapping of stone.

The Schillinger, Mesoudi, and Lycett (2014) study, however, represents another interesting case of convergence. I myself have used closed-cell foam in many of my flintknapping classes, starting in 2003, to serve as proxy stone cores for teaching students the strategic differences between core reduction methods, such as bifacial, Levallois, and blade technology. I gave each student a foam core and a little saw and asked them to saw off flakes in the appropriate series of removals. I did this precisely because I wanted to test their knowledge of the connaissance of each technology (the sequence and direction of each removal) *without* the interference of their poor savoir faire since they had not yet had time to develop adequate bodily gestures to execute each technology.[3] Thus, one can see a similar solution to removing the constraints of how hard it is to learn how to knap stone. The question is, how should we use such solutions?

A more recent experiment attempted to do the opposite of Schillinger, Mesoudi, and Lycett (2014) and my foam-core teaching method—that is, to learn what stone technology looks like when the connaissance/strategy of the core reduction is removed from the equation, leaving only the savoir faire/tactical know-how of individual flake removal. In a unique and rather brilliant experiment, Moore and Perston (2016) endeavored to eliminate strategic-level cognition as much as possible from the knapping procedure by randomizing platform selection, where an expert knapper is to strike on the core, between flake removals. The goal was to simulate what an assemblage of stone tools might look like under a rule of "least effort" flake production such as might characterize the earliest of lithic technologies in which only one flake was desired at a time. Further experiments along this line, which *utilize* rather than *ignore* the difference between tactical and strategic knapping skill, will move us much closer to an archaeology of pedagogy.

CONCLUSION

In this chapter I have endeavored to illustrate the importance of considering the dual structural oppositions between etic/emic perspectives and strategic (connaissance)/tactical (savoir faire) bodies of knowledge for making CT research materially explicit enough to accommodate Paleolithic data on lithic artifact production sequences. The differences between etic and emic perspectives are already recognized to some degree within CT research, given the indirect learning exemplified by Boyd and Richerson (2000) and my Figure 8.1. Many disciplines, however, have converged on a similar recognition of the indirect nature of cognition and the learning process. As Salikoko Mufwene has observed (see chapter 9), the indirect nature of social learning would make *cultural replication* a more accurate descriptor than *cultural transmission* for the process that interests us. The term *cultural replication* would avoid what Michael Reddy, a linguistic anthropologist, calls the *conduit metaphor,* a concept in spoken and written English that frames our language about language.[4] The framing ignores the construction of meaning in the mind of the listener by privileging the perspective of the speaker, both for the creation of meaning and as the responsible party for moving the meaning between interactors (Reddy 1979). Phrases like “get your thoughts *across* better” and “you still haven’t *given me* any idea of what you mean” exemplify the conduit metaphor. Reddy’s critique of the conduit metaphor demonstrates how frequently our language about language creates the fictitious idea that “ideas” are passing through the ether between interactors. The cultural “transmission” seen in Figure 8.1 as a series of hand-off events relies on the conduit metaphor and so perpetuates the conflict between the (false) sender-oriented metaphor in CT theory’s title and what we know about the receiver-oriented nature of cognition itself. The archaeologist Michael Schiffer (1999) has made this point explicit in his emphasis on how humans learn from the environment via an exclusively receiver-oriented perspective, including the communicative acts of other humans. Arguing that language is the most obvious but least omnipresent medium of communication, Schiffer proposes a three-interactor model for human inferences, with material culture—rather than language—acting as a vehicle for the majority of information humans glean from their environment. By replacing the typical linguistic two-body model of sender and receiver critiqued by Reddy, Schiffer advocates a model with a “sender” that alters the physical properties of an “emitter,” which then cues cognitive responses *(correlons)* in the mind of the “receiver” that inform the receiver about its environment. Each of the three roles (sender, emitter, and receiver) can be played by a person, an artifact, or even a natural phenomenon *(extron).* As material culture plays the role of emitter in most of Schiffer’s basic communication processes, the receiver-oriented approach should take on added significance for CT theory.

In building the Behavioral Approach to Cultural Transmission (BACT), I have endeavored to keep a receiver-oriented approach for how novice flintknappers learn their skill sets through their enculturating environment. This approach, as a result, relies heavily upon the strategic knowledge/tactical know-how distinction inherent in lithic technology. Given Mufwene’s question, therefore, should we not rename *cultural transmission theory* to *cultural replication theory* in order to avoid the demonstrable perils of Reddy’s conduit metaphor? It is too early to say. Boyd and Richerson (1985) already tried to move the discipline away from Cavalli-Sforza and Feldman’s (1981) original *cultural transmission* descriptor by emphasizing the name *dual inheritance modeling,* and that did not stick. But I do believe that the greater recognition and utilization of the perspectival difference between a sender and a receiver would go a long way toward making CT research more realistic for cases of craft production because it forces one to remember the physical process during a "transmission event." Thus, with certain technologies, adding the strategic knowledge versus tactical know-how distinction would encourage us to see strategic knowledge as a product of something short, an *event of transmission,* whereas tactical know-how is something that takes longer to acquire, as a product of a *process of development.* Rather than advocating another title, we can instead embrace the need for both the developmental *and* phylogenetic perspective when conducting research on how individuals acquire knowledge (Wolcott 1991).

In this chapter I have also endeavored to highlight the efficacy of considering in detail how the CT of a given technology can be affected by scaffolding of many types. From the six conceptual models I provide, the reader may ask, What is the utility of the scaffolding scenarios? Am I not going to peg specific archaeological NASTIES to each scenario? No, I will not engage in what can only be seen as guesswork at the moment. However, I will present a challenge. If more archaeologists can apply the quantitative and behavioral methods discussed here widely enough to produce sufficient assemblage data sets, we will begin to be able to test behavioral hypotheses derived from CT modeling against real Paleolithic data. To date, there are a limited number of archaeologists besides myself using these methods (Nigst 2012; Nigst et al. 2014; Scerri 2013; Scerri et al. 2014; Scerri et al. 2016). But if we can begin to construct larger difference matrices from the comparison of assemblages (as Tostevin and Škrdla [2006, Table 4] began for the Early Upper Paleolithic in the Middle Danube basin), we will improve our ability to make scientific progress, at least for the quantitative comparison of change through time in instructional learning sets. Having quantitative measures of what was or was not learned in different times and places is a first step toward making Paleolithic archaeology useful for testing hypotheses concerning CT. Imagine if Paleolithic archaeologists were able to calculate diversity values, such as F_{ST} values, from Paleolithic data to compare with F_{ST} predictions from agent-based models (e.g., Premo 2012b) and other population genetics–inspired modeling. Each scenario above can be modeled, even if the task is difficult. *If Paleolithic archaeologists can meet the modelers halfway, imagine what a developmental agent scaffold that would be for the growth of a theory of cultural evolution.*

In this chapter, I have provided only the briefest illustration of how Paleolithic archaeology should redesign its analytical approach in order to be more useful in the larger endeavor of building cultural evolutionary theory. My intent has been to point out the potential of Paleolithic data should the needed analytical changes be adopted and highlight conceptual areas where CT theorists and Paleolithic archaeologists can come together as closer collaborators, as has been done in other contexts (Premo and Kuhn 2010; Premo and Tostevin 2016). There is a productive traction for abundant research between the processual thinking of such modelers and the archaeologists who excavate and measure artifacts. This has been my experience with the exploration of the concept of generative entrenchment as applied to blade technology and compound tools in the Late Pleistocene (Tostevin 2013), a direct result of interacting with William Wimsatt at the University of Minnesota. And it is even true when the theorist (Wimsatt) did not have enough time to complete his flintknapping training in my lab. He certainly got the connaissance, if not sufficient practice in order to internalize the procedure as emic, savoir faire body knowledge.

NOTES

Many thanks to William Wimsatt for inviting me to the original workshop and for all of our productive discussions over the last few years. I would also like to thank Genevieve Tostevin for her help with the figures in this paper.

1. Boyd's Arizona State University biographical statement, https://webapp4.asu.edu/directory/person/1952328, accessed September 1, 2014.

2. Tostevin (2012, chapter 4) provides an illustrated discussion of the flintknapping process and these variables, showing their visibility from the point of view of the observer versus that of the performer.

3. My thanks to Liliane Meignen, one of the founders of the French *chaîne opératoire* school of lithic analysis, for the idea of using a substitute core when teaching students who have not yet achieved sufficient savoir faire skills to flintknap stone themselves. Dr. Meignen advised me in 1993 to use large raw potatoes as cores. I tried this approach for a few years when I first began teaching myself but found that the potato "flakes" were too messy, whereas the foam cores and flakes could be taken home by students as teaching kits.

4. My thanks to David Valentine for introducing me to Reddy's article many years ago.

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