McDONALD INSTITUTE CONVERSATIONS

Towards a Broader View of Hunter-Gatherer Sharing

Edited by Noa Lavi & David E. Friesem

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With contributions by
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Noa Lavi & David E. Friesem,
Cambridge, October 2019

Chapter 14

The sharing of lithic technological knowledge

Gilbert B. Tostevin

The sharing of lithic technological knowledge among foragers, as a subject, encapsulates two of the central themes of this book. First, the item being shared is not a subsistence item such as game meat, so frequently the focus of hunter-gatherer studies. Second, lithic technological knowledge is something which must be shared through practice to be learned, and as Lavi & Friesem state in their introduction to the conference that led to this book, the significant value of studying a practice 'lies in its ability to open a window to more intangible aspects of life such as sociality, morals, values, ideas, knowledge, daily conduct, relationships and social, self and environmental perceptions'. The knowledge of how to flintknap is certainly an intangible component of the lived experience by which the world of hunter-gatherers is constituted, or was, until very recently for most foraging populations. Yet the material requirements of the sharing and learning of flintknapping skill, which we can take as knowledge put into practice, is in many ways counter-intuitive. The practice produces the most tangible of results, in the form of artefacts that preserve across the entire duration of the archaeological record, almost regardless of the preservational environment. This archaeological ubiquity gives non-specialists the impression that lithic technology is as readily learnable as it is abundant. Yet flintknapping as a learnable performance in real time is more ephemeral than most material practices, including pottery, textile weaving, and basketry. The delivery of a blow that produces a flake is so fast in its execution that learning the bodily performance with anything akin to accuracy through a single observation is difficult and unlikely. And deciphering the behavioural specificities of a sequence of such blows through the examination of a single artefact varies greatly depending upon a number of technological and contextual variables. As a result, the successful sharing of this intangible content imposes distinct material requirements for its complete acquisition by the receiver. The nature of these requirements are such that anthropologists and archaeologists may need to anticipate a greater range of results from the sharing of lithic knowledge among foragers than from the sharing of other intangible bodies of knowledge, such as ideas and beliefs (Tostevin 2019). Given flintknapping's counter-intuitive nature, the processual understanding of how it is learned, practiced, and shared by modern human knappers has not translated well to the world of the experimental archaeology, cognitive sciences, and fields such as cultural transmission theory, which utilize stone tool technology as a subject from which to learn how knowledge was shared in the past. Indeed, some recent experiments within these fields have incorrectly characterized the process by which flintknapping skill can be transmitted. This paper, which presents a processual discussion of what anthropological archaeologists know about how flintknapping knowledge *can and cannot* be shared, thus comes at an opportune time to contextualize these experimental results. At the same time, such a discussion can help clarify where future experimental work is needed to test the boundary conditions for when the intuitive perspectives of modern human knappers constitute appropriate vs. inappropriate assumptions to use in interpreting learning processes across the temporal scale of human evolution.

Framing the question

One of the questions I am most frequently asked when I mention my interest in how our human ancestors learned to make their stone tools is, *when did hominins first start to teach this knowledge?* This is an important and omnipresent question but it is not my proximate goal for this paper. Instead, I will treat it as an ultimate goal towards which the discussion I offer here is aimed. By focusing on the gradual accrual of mechanisms available to foragers for sharing 'knowledge put into practice', I hope to emphasize (or, perhaps, re-emphasize in a new frame) perspectives from modern flintknappers and anthropological archaeology that will help, in the end, to answer that ultimate question.

The goal of the present paper is thus not to summarize the current data on when we first recognize the teaching of flintknapping in the archaeological record. That goal itself is worthy of treatment but, for the purposes and scale of this volume, the necessary data are compromised by two limitations that make the results more informative about these limitations than about the evolution of pedagogy itself. First, site formation processes result in the behavioural resolution of lithic data decreasing as the age of the sites increase, biasing our view of pedagogy towards recent periods. Second, the interpretation of the different forms of preserved lithic data expose more about methodological problems in archaeological interpretation than about when the sharing of lithic technology actually began. The contrast between the interpretation of refitting and typological data will help illustrate this point. For instance, a synthesis paper would be able to discuss a number of extremely well-preserved archaeological sites that most scholars would agree can be interpreted as the earliest solid evidence of some type of flintknapping 'school' or at least a close spatial association between the debris of a skilled knapper's activity and that of a number of individuals of lesser skill. These likely flintknapping apprenticeship sites would include at a minimum three French localities, Étiolles (Pigeot 1987, 1990), Pincevent (Bodu et al. 1990), and Solvieux (Grimm 2000), and one Danish site, Trollesgave (Fischer 1989, 1990; Riede 2006). The close synchronicity of these sites at the end of the European Upper Palaeolithic, however, may be less relevant than their geoarchaeological commonality: In each case the artefacts are encapsulated within very short occupations with little taphonomic distortion during the site formation processes which led to their geological preservation. Such geoarchaeological contexts preserve artefact associations that allow analysts to reassemble individual nodules of rock through the refitting of most of the removed flakes back onto cores, assuming that they were in fact left at the site by the knappers (e.g. Goring-Morris et al. 1998). Through the counting of knapping errors vs. successful removals throughout the reduction of a nodule, analysts may recognize differential skill levels between very complete refitted sequences. Such sites are rare, however, both in terms of taphonomic preservation and the completeness of the refittings, and they get rarer the further back in time one looks. These four sites are also the creations of modern humans rather than pre-modern hominins, making the interpretations less controversial. Yet it is notable that none of the few sites with extensive refitted sequences from pre-modern contexts, such as Lokalalei 2C of the Oldowan (Delagnes & Roche 2005), Boxgrove of the Acheulean (Pitts & Roberts 2000; Hallos 2004, 2005), or Maastricht-Belvédère of the Middle Palaeolithic (Schlanger 1995, 1996), have been argued to evidence a pattern of differential skill levels to suggest anything akin to a case of apprenticeship.

If rare refitting data can be demonstrative (if not straightforward), the interpretation of the pedagogical significance of specific artefact types that are more frequent in the archaeological record, such as Acheulean handaxes or the blade cores of later periods, is far from clear. On the one hand there are archaeologists (including McPherron 2000; Davidson 2010; Moore 2011) who conclude that simple rules of production, acquired without instruction, can produce the variability seen among Acheulean handaxes. On the other is the view that complex forms of instruction and apprenticeship are necessary for their production (e.g. Wynn 2002; Shipton 2010; and Hiscock 2014). There has even been a recent argument that these artefact forms are as genetically controlled as birds' nests (Corbey et al. 2016). As the commentary within Tennie et al. (2017) makes apparent, Palaeolithic archaeology has a long way to go in developing a quantitative and anthropologically sound body of archaeological theory to disprove some of these diametrically opposed hypotheses about artefactual learning in the earlier periods of the archaeological record.

Therefore, rather than jumping into the synthesis of contested data, I will take the present opportunity to examine the process of sharing as it relates to the learning of a material skill as a way to highlight what we would expect for the learning of flintknapping skill under the assumptions of both behavioural ecology as well as the perspectives of modern human artisans engaged with this skill. Taking Whallon's (2011) framework within which to view the role of information in hunter-gatherer bands as a model, this treatment will also highlight where our modern assumptions for such a process may be of suspect utility. I will explore this framework through a series of questions, including: Why should one share flintknapping knowledge? What are the limits on sharing such knowledge? How is the knowledge structured in practice and how does this structure affect sharing and experimental investigations of learning? What does it mean to share a process that is composed of the interactions of different cognitive, artefactual, and agent-dependent scaffolds? What are the repercussions of sharing space as well as sharing time within the process of learning flintknapping? What are our current problematic assumptions related to when flintknapping knowledge must be shared to be learned vs. learned through self-guided, trial and error learning?

Why should one share flintknapping knowledge?

In comparison to the sharing of food and other resources, how is the sharing of lithic technological knowledge different? The ethnographic literature on flintknapping, when limited to foraging societies (e.g. Australian groups in Tindale 1965; Gould et al. 1971; Hayden 1979; Gould and Saggers 1985), is not abundant and unfortunately is not as well documented as other aspects of hunter-gatherer behaviour. Our better documented ethnographic descriptions of the learning of flintknapping come from populations (mostly agriculturalists, horticulturalists, and herders) which no longer rely on stone cutting edges as their main interaction with the material world (Brandt et al. 1996; Clark 1991; Gallagher 1977; Hayden & Nelson 1981; Sillitoe and Hardy 2003; Stout 2002; Weedman 2000; White and Thomas 1972). Yet, as with other shared resources used by foragers, one can use behavioural ecological theory to make predictions to supplement the lessons learned from ethnographic observations to inform our framework for studying behaviours deeper in prehistory.

From evolutionary theory, one would predict that as soon as an individual's costs of procuring raw material and making lithic cutting edges were outweighed by the benefit s/he received from the cutting edges' improved access to food resources, whether in the form of direct meat/plant food processing or through the shaping of other tools (e.g. wood) for food acquisition, there would have been evolutionary selection for behavioural incentives to encourage kin-based sharing of the skill to produce those edges. In other words, hominins would have assisted their kin in the learning of the creation and use of stone tools, to the extent that their cognitive capacities for shared attention would have allowed (a caveat which will be explored in more detail below). Following Torrence's (1989a, b) focus on time as the limiting resource for modern human foragers and thus the most suitable unit of optimization within a lithic economy, one would predict that the cost to the facilitator of this sharing would likely be in terms of the added time spent in providing raw material, which would depend upon the interaction between toolstone provisioning and the mobility strategy (per Surovell 2012), and in the time lost as delays while slowing activities to assist the learner's observation, as is done with the learning of hunting skills in living foragers (MacDonald 2007). Such costs could be as low as tolerated scrounging of toolstone during any knapping event (equivalent to chimpanzee mothers allowing infants to pull scraps of food from their mouths (Winterhalder 1997)), to intentional initiation of knapping at locations already provisioned with stone (Shea 2006), to the high costs of planned forays to locations with distant stone even if for only the purposes of information gathering on distant locales (Whallon 2006). The examples of the costs above are clearly incremental through evolutionary time and not all of them are likely to have been relevant to early sharing of flintknapping knowledge, but are provided here to illustrate the range of possibilities.

Given the likely existence of even minor costs, one would predict that the sharing of flintknapping knowledge would follow Hamilton's Rule under kin selection (Hamilton 1964), in which the cost to the actor must be less than the benefits to the receiver, devalued by the degree of relatedness between actor and receiver. Such costs would include the life history trade-offs implicated in Trivers' (1974) parent-offspring conflict, although the costs associated with lithic technology would pale in comparison to the direct reproductive costs usually associated with such life history conflicts. Additionally, the sharing of flintknapping knowledge would also follow Trivers' (1971) rules for reciprocal altruism among non-kin. This would be more likely through time as hominin social structure evolved from the last common ancestor with the non-human apes, to take on the unique form of living human foragers in which the majority of co-residing adults are unrelated (Hill et al. 2011) and reciprocal altruism rather than kin selection dominates food sharing (Allen-Arave et al. 2008). Given this transition from a social structure of chimp-like kin selection and sex biased natal dispersion to a social structure of fictive kinship with flexible membership (Read 2011), one would predict that the selective pressures for knowledge sharing would have adjusted accordingly.

The role of stone tool cutting edges also changed within the hominin adaptation during these changes to hominin social structure. As Shea (2017) argues using the large-scale analysis of variation in the technological treatment of stone (his Modes A–I, Shea 2013, rather than epistemologically suspect industrial types), the use of lithic cutting edges became habitual by 1.7 million years ago, rather than just occasional – as with non-human primates – as before this date, involving the greater foraging radii needed for a more carnivorous biped. This essentially pushed hominins further along the trajectory of increased logistical mobility relative to that of non-human primates. By

0.3 million years, stone tool cutting edges had become essential or obligatory for a successful bipedal hunter-gatherer adaptation, as seen with recent living foragers. Through these changes in stone tool use from occasional, to habitual, to obligatory, I would add to Shea's reconstruction that the increased need throughout the Pleistocene for individuals to master the skill of flintknapping would have created a context for a cascade of selective pressures towards the cognitive, emotional, and social parameters associated with the prosociality of living humans. Despite our obvious selfish natures and propensity for Machiavellian intrigue, human cooperative behaviour stands in striking contrast to the emotional instability and uncooperative sociality of chimpanzee societies. Kim Sterelny's *The Evolved Apprentice* (2012) makes an eloquent argument in this direction, positioning flintknapping within the gradual evolution of information-sharing practices across generations that resulted in both the cooperative foraging adaptation and prosocial mental abilities of modern humans. His account solves many of the problems associated with the difficulty of evolving cooperation in game theory out of a world of cheaters. His argument also fits much of the logic of niche construction theory (Laland & O'Brien 2011), whereby the future inheritance of the environment that is shaped by current behaviour allows for the evolution of more complex structures than through the oscillation of traditional selective forces. In his account, our prosociality could have resulted from the selective forces of niche construction during the tumultuous Pleistocene Epoch, requiring us to 'Stay Calm, and Carry On Knapping!', as I like to put it. Hiscock (2014) has taken this logic further, if perhaps into more controversial territory, considering the evolution from one lithic technology to another as merely the incremental elaboration that facilitates competition within a social niche, rather than the evolution of new technologies to solve functional requirements which could not already be solved with existing cutting edges. While each of these theoretical perspectives has its attractions as well as disadvantages, they all point to the need to consider how the changing mechanisms by which lithic technological knowledge was shared could have shaped both the large scale pattern of lithic technology itself and the shape of the hunter-gatherer adaptation as well.

But to what extent *can* one share one's flintknapping knowledge?

While behavioural ecological theory predicts that individuals should share lithic technological knowledge when possible and that the archaeological record should display an increasing role for such sharing as material culture took on a more central role in the bipedal foraging adaptation, the hard question remains, *is it possible to really share one's knowledge of such a skill at all?* This may sound like a strange question but the fact is that conceptually half of what constitutes the knowledge to do the activity – to actually perform the appropriate choice in the technological procedure once one knows what the appropriate choice should be – is not vocalizable nor expressible in gesture without its actual demonstration. It can only be shared as a performance that is followed by the observer practicing the motions her/himself, through abundant repetitions, in order to replicate that uncommunicable knowledge within her/himself. As I have put it elsewhere (Tostevin 2012, 2019), it is necessary to make the observer's etic (cognitively separate) perspective into an internalized, emic (internal) perspective as a knapper through the observer's own practice. This is due to the fact that the flaking gesture 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 & 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 consequences of the action. This near simultaneous action-result package makes it impossible for a knapper to consciously understand all of the neuromuscular components of the action and so put them into any communicative act other than repetition. The physics of knapping also make it impossible to slow down the gesture to a speed at which an observer can, by simply looking, perceive all of the necessary bodily details. If this were otherwise, none of the controlled experiments in flake fracture mechanics, from those of fractographers (Tsirk 2014; Quinn 2007) to those of experimental archaeologists (Speth 1972, 1974, 1975, 1981; Dibble & Pelcin 1995; Pelcin 1997; Dibble & Rezek 2009; Rezek et al. 2011), would have been necessary. Conversely in other material media, we can just observe and ask potters and basket weavers how they perceive the skill in order to learn much (although certainly not all!) of their skills. And to judge by the more recent attempts at flake fracture studies (Magnani et al. 2014), even these experimental approaches are not able to disentangle the known variables under the control of the knapper.

The description above relates to the basic behavioural unit of flintknapping, the striking off of an individual flake. The order and strategy behind a sequence of flakes, if not their removal, however, are declarative knowledge and can be communicated with greater ease. Thus flintknapping is like all other items of material culture, in that to learn how to make the item is to learn two different and highly structured bodies of knowledge, i) knowing what you *should* do in the conceptual sense, the readily communicable knowledge or *connaissance* of the behavioural gesture in the parlance of the French *chaîne opératoire* school (Pelegrin 1990); and ii) 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 (i.e. the relatively uncommunicable know-how or *savoir-faire*, as it is termed in the French school). This is a distinction which is also recognized in the cognitive sciences and has been further clarified in recent experimental imaging analyses (Stout & Khreisheh 2015; Stout et al. 2015). In another paper (Tostevin 2019) which could serve as a companion piece to this one, I unpack the *connaissance* vs. *savoir-faire* distinction, following the work of others (Apel 2008; Wynn and Coolidge 2004) and illustrate how the entire lithic operational sequence can be understood as a combination of flintknapper decisions (nodes) that are reflected within either tactical domains, comprising the non-declarative know-how of *savoir-faire* involved with individual flake production, or within strategic domains, involving the knowledge (*connaissance*) of the plan for a sequence of removals within core reduction, including contingency plans for error corrections. The most significant ramification of this distinction is that there is a greater fidelity of transmission between a demonstrator's and an observer's strategic knowledge after one or two observations but less fidelity without longer exposure and practice between a demonstrator's tactical know-how and that of an observer (a subject to be explored below). The second most significant ramification of this distinction is that the patterning at each decision node is as archaeologically visible to modern lithic analysts as it was to the prehistoric observer at the beginning of their etic learning experience, before their own trial-and-error practicing transformed the etic to an emic understanding of the tactical know-how. This is a result of most (although not all) of the knapper's decisions (conscious, unconscious, and errors) being preserved as physical attributes on the resultant artefacts which can serve as etic proxies for later analysts. If lithic technology were not reductive and did not preserve the marks of previous removals on the dorsal face of each flake and on the surface of each core, this would not be possible.

The relatively strong know-how vs. knowledge distinction in flintknapping may result in the incomplete sharing of flintknapping knowledge between individuals to a greater extent than with other types of knowledge. *All human learning* of course has such a potential since it is a receiver-oriented process (Thayer 1967; Schiffer 1999), despite our perverse linguistic willingness to describe learning as a sender-oriented 'communication', what Reddy (1979) calls the Fallacy of the Conduit Metaphor. Yet the knowledge sets of bodily action and material culture production have by necessity more of an emphasis on know-how and so it is significant that ethnographers of foraging societies in the present volume, such as Gardner and Hewlett et al. (and Hewlett et al. 2011), consistently note the de-emphasis of verbal instruction in most foraging skill sets, even when there is danger or disadvantage in the failure to learn. To me, it remains a fascinating subject of further research whether this overall de-emphasis on verbal instruction is a result of an evolved pedagogical efficiency in letting learners of most foraging tasks 'observe and then practice', rather than 'listen and then do' (as with the more non-material learning of non-foraging societies), or if the restrictions on verbal instruction among what Gardner calls 'taciturn' foragers is a result of the de-emphasizing of superior knowledge among the knowledgeable as part of the foundational schema of the egalitarian ethos (Hewlett et al. 2011). Of course, it will be important to keep in mind the fact that multiple processes may result in similar foundational schema among different forager groups, as Boyette & Lew-Levy (this volume) show through the contrast in why resource sharing is pursued by the Aka and Ngandu through the action of different core cultural values.

The importance of the tactical vs. strategic knowledge distinction for the experimental investigation of the sharing of flintknapping knowledge

Unfortunately, it is precisely the distinction between tactical know-how and strategic knowledge which has been lost within several recent and important experiments designed to investigate the cognitive requirements for the cultural transmission of flintknapping and the evolution of language during human evolution (the exception being Stout & Khreisheh 2015 and Stout et al. 2015). Morgan et al. (2015), in an impressive and influential study, trained 184 individuals in flintknapping under five varying mechanisms of transmission. The mechanisms included 1) 'reverse engineering' in which the naïve observer was given a hammer stone and a core and shown stone tools but never shown a knapper in action; 2) 'imitation/emulation' in which the naïve observer was shown a knapper in action over a sequence of flake removals, simulating imitative learning (Whiten et al. 2009) in which the means to achieve the goal as well as the goal was visible, but the observer was not allowed any interaction with the demonstrator; 3) '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; 4) 'gestural teaching' in which the demonstrator could interact with the naïve observer through unlimited gestures and physical motions in an effort to improve the transmission but was not allowed to speak; and 5) 'verbal teaching' in which no limits were placed on the demonstrator's communication abilities. What is immensely positive in the experimental design of Morgan et al.'s study is first, the large sample size of learners that would allow for the first time a knapping experiment to produce statistically analysable results. Second, the participants were articulated into transmission chains of learners teaching learners in iterations of 5 to 10 'generations' to test the fidelity of the transmission in the form of independent evaluations of the success of each blow and the efficacy of each flake product. What was missing from the study, unfortunately, was the realization that flintknapping tactical know-how, which was what was being measured on the resultant flake products in each transmission chain, cannot be learned in 5 minutes, which is all that each naïve observer was given to practice and learn themselves before being required to demonstrate to the next naïve observer in the transmission chain. Had the study tested the transmission of strategic knowledge, such as the discrimination ability of the observer to learn what steps should be taken in a core reduction without having to flintknap themselves, the results would have had some meaning for the research question at hand. However, the participants were being tested on their tactical know-how without giving them any time to generate that type of knowledge. Shea (2015) argues that at least an hour is necessary to teach Early Stone Age flaking techniques and that does not include the learner's practice time, whereas Stout and Chaminade (2007) provide data showing that 4 hours is insufficient for developing more than a little motor skill improvement with Oldowan knapping. The results of the Morgan et al. (2015) study show that the transmission mechanisms all ultimately failed, as even the best performing mechanism at the end of its transmission chains produced results as poor as the most sparse mechanism, reverse engineering. The results are thus clearly understandable from the point of view of the tactical/strategic distinction, but this distinction was not recognized during the interpretation of the results, producing an error in concluding that 'verbal teaching' constitutes the only statistically successful mechanism for transmitting flintknapping skill beyond the level of the Oldowan.

Other experimental studies designed around transmission questions have also recently declined to take advantage of the standard flintknapper's wisdom concerning the tactical/strategic distinction. Two experiments designed and executed by the same team endeavoured to replicate aspects of flintknapping to test different concepts of the cultural transmission of stone tool making (Lycett et al. 2015). Kempe et al. (2012) endeavoured to evaluate the effects of size mutation by asking naïve participants to use a tablet computer's touch-screen to resize an image of an Acheulean handaxe to that of an example image. In a separate study, Schillinger et al. (2014) investigated shape mutation in the copying of an Acheulean handaxe by asking participants to use a stainless steel table knife to carve the shape of a model Acheulean handaxe out of a standardized plasticine block. While their overall purpose in creating a 'model organism' context to stimulate cultural transmission research (Lycett et al. 2015) was both laudable and insightful, neither experiment made any effort to approximate the material reality of the process involved in acquiring or utilizing the tactical know-how necessary for flintknapping. Studying the effects of size mutation (Kempe et al. 2012) might arguably be a question of strategic knowledge but surely the rate of shape mutation (Schillinger et al. 2014) relies upon the fidelity of the transmission of tactical know-how far more than strategic knowledge. Removing tactical know-how from the experiment made the recruitment and retention of participants far easier but certainly compromised the applicability of the results for the understanding of the origin of shape variation in flintknapping stone.

In all of these examples, the rationale for the experimental design not to include the meaningful distinction between tactical and strategic knowledge is understandable as a practical decision. The length of time it takes to generate tactical knowledge in a naïve participant is a burden, particularly with the typical college student participant pool. Those well executed studies which pay due attention to the tactical vs. strategic distinction in fact can suffer from participant drop-out and/or failure to follow the procedures (Bamforth & Finlay 2008; Ferguson 2008). Yet the results of a study are only as meaningful as the experimental design. So it is to be hoped that these studies will be followed by additional work to apply this distinction within longitudinal studies, as has been done so successfully elsewhere (Stout et al. 2015; Stout & Khreisheh 2015), but with the larger sample sizes these studies demonstrate so well.

What does it mean to *share* flintknapping knowledge?

The types of transmission mechanisms involved in Morgan et al.'s (2015) five transmission chains have another name within the literature of the anthropology of education, developmental psychology, and development approaches to cultural evolution, namely scaffolds. I would prefer to call such mechanisms scaffolds, building off of the artefactual metaphor for the role of teachers' and others' behaviours that facilitate a child's development (Greenfield 1984; Bickhard 1992; Lave & Wenger 1991), because the term places a dual emphasis on the importance of 'sharing' within the acquisition of flintknapping knowledge. Not only is willing transmission by a demonstrator an act of sharing with a learner but in fact certain cognitive faculties must be 'shared' (as in, 'held in common') between the demonstrator and the observer for certain mechanisms to be viable, in order for one individual to realize the need to aid the knowledge acquisition of another. Wimsatt & Griesemer (2007) recognize three types of scaffolds:

1. *Artefact Scaffolding*: 'artifacts can scaffold acts when they make acts possible, feasible, or easier than they otherwise would have been' (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' (2007, 65). I take the cognitive capacities of prehistoric actors to fall in this category.
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' (2007, 66).

In a separate paper (Tostevin 2019), I investigate seven conceptual scenarios of the cultural transmission of flintknapping knowledge, distinguishing between the fidelity of tactical know-how vs. strategic knowledge in each case, according to the gradual augmentation of each of these three types of scaffolds. We can use these three types of scaffolding to explore the process of sharing flintknapping knowledge according to what is being shared: space, time, and directed mental states.

Sharing space

The sharing of physical proximity is the first, basic aspect of sharing between a knowledgeable individual (the knapper) and a naïve observer. Hewlett et al. (in this volume) explore the dimensions of the social sharing of space among contemporary foragers and provide a useful discussion to contextualize and scale the arguments below.

Sharing physical proximity involves a form of social tolerance of the naïve observer by the knowledgeable individual, that provides the observer with access to artefactual scaffolds, such as a hammerstone, core, and resultant flakes, even if the knapper is not an intentional, active developmental agent scaffold, because s/he is unwilling to share her/his attention or is cognitively unable to recognize the lack of knowledge in the other (i.e. lacks the infrastructural scaffold of a theory of mind, *sensu* Dunbar 2003). The physical proximity of objects in motion can provide the learner who possesses the cognitive infrastructure scaffolding of emulation learning (for the goal of an action, *sensu* Tomasello 1996), with enough stimulus enhancement (Charman and Huang 2002; Franz and Matthews 2010; Matthews et al. 2010) to learn the object affordances of basic direct, hard hammer percussion. This etic understanding that a hammerstone can be wielded against a core to produce a sharp flake would only be actualized as true, emic knowledge of the percussive flaking gesture in the observer once s/he conducted enough trial-and-error practicing to discover the basic variables of the process for her/himself: 1) identify a location of core geometry that offers a convexity opposite a platform surface on the core that has an angle less than 90 degrees to the convex surface (for conchoidal initiation); 2) rotate, 3) turn, and 4) tilt the core across the three positional axes to line up the target platform with the percussor, such that the angle of blow of the striking gesture, aimed as a vector outward to the dorsal surface of the core, is within the 90 degree arc between the surface of the platform and a vertical blow to the platform; 5) identify the platform depth/thickness from the edge of the platform as the point of percussion to strike; and 6) strike with at least the minimum force necessary to dislodge the mass determined at the platform by the platform depth and the exterior platform angle (between the outside of the core that becomes the dorsal surface of the flake and the platform). With these six requirements, I have intentionally used Mark Moore's (2010) five ideational elements of his grammar of action for his basic flake unit but augmented them with the platform variables identified by controlled knapping experiments as those that determine flake size (e.g. Rezek et al. 2011). This is the flaking behaviour which Shea (2013) would call Mode C, the reduction of a pebble core or non-hierarchical core. Yet if the stimulus enhancement and subsequent trial-and-error learning were not sufficient for accurate replication, it is possible that the demonstration of direct hard hammer percussion could stimulate less complex behaviours in the learner, such as the use of a stone percussor against an anvil without a core in between, in which case Shea would call it Mode A and is a behaviour well known among the Anthropoids in both South American and Africa (Westergaard 1995). Alternatively, if bimanual percussion were not learned sufficiently but the affordance of the core was recognized, bipolar percussion (hammer and anvil with the core in between) might be the result. In this case, Shea would call this Mode B, which has been proposed as an antecedent to the Oldowan at the Lomekwi 3 locality in Kenya. Bipolar percussion does not require the same attention to the detail of platform angle in Requirement 1 above, since bipolar percussion produces shearing and wedge-initiated fractures (Cotterell & Kamminga 1987) that do not require an acute platform edge. While the recognition of the appropriate core geometries, correct platforms, and tilt angles of Mode C (bimanual direct percussion) were initially beyond Kanzi the Bonobo (Savage-Rumbaugh and Fields 2006; Schick et al. 1999), subsequent training of Kanzi as well as his sister Pan-Banisha resulted in the successful application of all 6 requirements above (Roffman et al. 2012). No non-human primate has been seen in the wild making Mode B or C tools, however.

It should be pointed out that the strategic knowledge acquired by the learner in the above scenario was a result of low fidelity cultural transmission (i.e. object affordances through stimulus enhancement) but the tactical know-how acquired by the learner was not a result of any cultural transmission but rather independent trial-and-error learning, what Tennie would recognize as within the 'zone of latent solutions' of a given species (2009; Tennie et al. 2017). Within the same level of physical proximity and non-pedagogical intent on the part of demonstrating knapper, a difference in the infrastructure scaffolding of the learner in the form of the cognitive capacity to use imitation learning (Whiten et al. 2009), in which the observer would pay attention to the actual sequence of movements (the means) to achieve the goal, would allow the learner to acquire the knowledge content through a different set of mechanisms, even if the resulting content were the same. Specifically, imitation learning would allow the observer to utilize all of the details of the use of the artefactual scaffolds present, rather than independently innovating a way to use them to achieve the goal (through emulation). If the core reduction demonstrated was simple, one would anticipate that the speed of acquisition of both tactical and strategic knowledge would be the same. If, however, the core reduction sequence was longer, the imitation scaffold would produce greater fidelity in the strategic knowledge and a likely faster acquisition of the tactical know-how as the learner used the demonstrator's flake products as artefact scaffolds. But the longer reduction sequence would involve the demonstrator and the learner in another form of sharing, namely that of *time*.

Sharing time

The longer the reduction sequence, the longer the physical proximity must be maintained for it to be learned by direct observation and the greater likelihood that the demonstrator would terminate the sequence before it is complete in order to devote time and energy to other living tasks. It is clear from the study of refitted sequences and distinctive raw material units that complete core reductions sequences were not always (or perhaps even frequently) executed all at one time in one location in the past but instead were fragmented across the landscape as the knapper practiced mobility in the pursuit of a livelihood (Hallos 2005; Turq et al. 2013). Yet if the knapper were able to share her/his time and joint attention with the learner, by means of a shared cognitive scaffold such as the capacity for triadic attention (Tomasello et al. 2005), observational learning could be far more faithful to the demonstrator's content, at least for strategic core reduction knowledge. It is also likely that tactical know-how acquisition would be speeded up, to the extent that the demonstrator could provide better angles of view and/or directly intrude on the learner's practicing through the readjustment of the core and hammerstone, etc., as Ferguson (2008) has shown through his own experiments to be efficacious in improving learning results among modern knappers.

At this point, the knapper and the learner are sharing a joint intention and time to produce a learning environment, such that the typical primatological situation of mere social tolerance producing physical proximity is replaced with true social intimacy in which the learner can be enculturated across many media (components of lived experience) while engaged in learning one specific content. This is the level of sharing and scaffolding that constitutes the social intimacy concept explored in Tostevin (2007), fittingly also within a McDonald Institute for Archaeological Research Monograph. It is also at this point in the incremental augmentation of the scaffolding and pedagogical environment where the knapper could do her/his utmost to assist the speedy acquisition of both strategic and tactical knowledge. As such, this is the point at which I would predict that sufficient fidelity in the transmission of the strategic knowledge of core reductions would produce ample variation in core reduction complexity between groups, within the range of equifinality between core reductions and their resultant flake products, for cultural drift to produce geographical variation in reduction strategies between populations of hominins. With the appearance of such variability between lithic operational sequences, the consistent fragmentation of the sections of the operational sequence across the localities of logistical mobility of the group would produce consistently different exposures of parts of the operational sequence to individuals of different groups, with different degrees of social intimacy. Specifically, as cores are reduced for blanks and reshaped through retouch into tools at base camps and raw material workshops, but not at logistical foray locations around the taskscape of the group's range (*sensu* Ingold 1993), the domains of core reduction would have a reduced visibility relative to the mobile tool kit transported onto the pathways of the landscape.

This concept of taskscape visibility, defined as the relationship between where, when, and with whom a cultural trait, such as a flintknapping behaviour, is performed and the possible transmission modes available for promulgating the trait into the next generation, is based primarily upon archaeological style theory, from Wobst (1977) to Wiessner (1983) to Sackett (1990) to Carr (1995). To problematize this theoretical foundation, 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, b), the simulation evaluated the equilibrium diversity of two selectively neutral traits that differed only in their taskscape visibility (i.e. 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. Further, the formal demonstration of different equilibrium diversity levels resulting merely from different taskscape visibilities lends more credence to the results of archaeological studies which use differences among core reduction methods vs. the differences among mobile tool kit morphologies across assemblages to inform on the likely overlap or not between enculturating environments of social intimacy among hominin populations (Tostevin 2007; Roussel et al. 2016).

Conclusion: how do we test our assumptions about *when* a given lithic technology *must* have been shared?

As demonstrated in the above discussion of Premo & Tostevin's (2016) test of the effect of taskscape visibility on selectively neutral traits, it is necessary to test, even with such abstract means as agent-based modelling, the principles derived from the application of evolutionary theory, ethnographic analogy, and archaeological middle-range theory. Eventually, the 'ideas' must be exposed to an experimental arena outside of an archaeological application to see if they perform as expected. In this case, an actualistic experiment was impossible and so an agent-based model served the task well. Future work of this type is clearly called for and currently underway. Yet the processual and theoretical discussion I have provided in this paper, as with that of Tennie et al. (2017) who seek to reset the null hypothesis so that technologies are assumed not to be the result of cultural transmission mechanisms until proven otherwise, demonstrates that the study of the sharing of lithic technological knowledge faces some serious experimental hurdles for testing our predictions, whether based on modern knappers' understanding of their trade, on evolutionary theory, or on the concepts of learning mechanisms derived in cognitive science laboratories. These hurdles currently prevent the testing of our judgment of what technologies in which periods *absolutely* required the sharing of knowledge according to specific transmission mechanisms. We can likely agree on the ends of the chronological spectrum

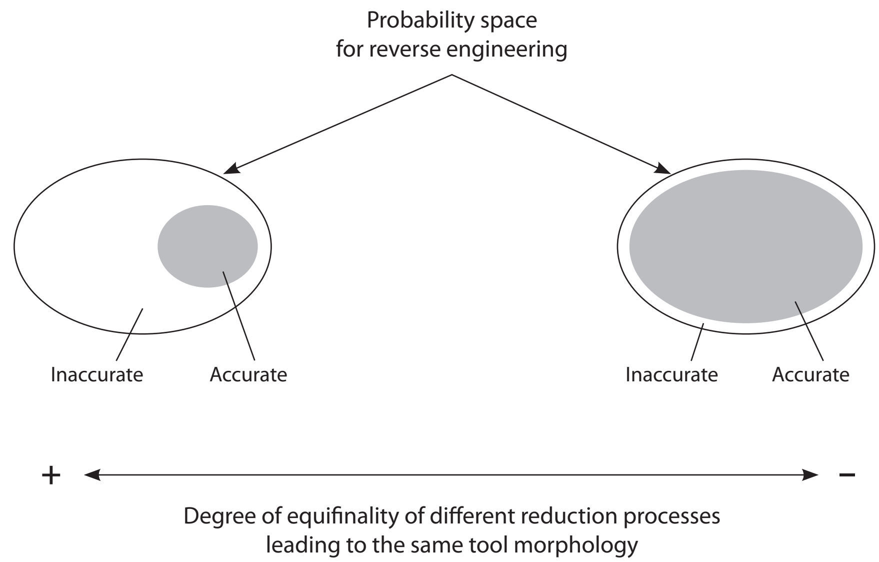

Figure 14.1. *The relationship between the assumptions of the degree of equifinality of core reduction processes that could lead to a given stone tool morphology and the likelihood of the accurate reverse engineering of the exact core reduction method responsible for the tool.*

in terms of the likelihood of being a product of cultural transmission but not on most of the archaeological record in between. Part of the problem is that these mechanisms are in fact subtle, observable mostly within controlled laboratory settings, and thus unlikely to be amenable to prehistoric recognition without serious experimental work to establish boundary conditions around specific technologies' probability spaces. As an example, consider Figure 14.1, which represents two views of how likely it is to accurately reverse engineer (Rekoff 1985) the core reduction methods that produced a specific lithic retouched tool based on exposure to the tool only, as in a scenario of stimulus diffusion (Kroeber 1940; Tostevin 2007). At the bottom of the figure is an arrow showing the spectrum of different assumptions about the amount of equifinality within core reduction (i.e. the number of core reduction methods that could produce the given tool). The greater the range of methods that produce a similar tool morphology, as seen on the left, the greater the chance of the reverse engineering finding a successful method of replicating the tool that is in fact not the accurate method in this case but produces the same result nonetheless. On the right, the assumption about the degree of equifinality, being extremely small, makes the likelihood of an accurate reverse engineering among the remaining available methods much more likely. The problem is that, at the moment, we have no independent reference to use to establish on which side of the figure a given core technology lies.

Yet this figure also replicates the basic problem with testing arguments based on the latent zone of solutions concept. This is apparent if one simply replaces the 'Probability Space For Reverse Engineering' title with the 'Probability Space For Independent Innovation within a Species' Zone of Latent Solutions'. Yet I am optimistic that careful and extensive experimental programs can be devised that would allow the new power of computer-based 3D characterization to quantify at least the range of flake products producible from a given core reduction method. This approach would allow the quantitative comparison of equifinality to ground specific technologies within the theoretical spectrum of Figure 14.1. In this way, it will be possible to test and disprove our previous assumptions through the application of the future research directions proposed by Tennie et al. (2017, 668) as well as others, including: 1) the need to quantify a lithic technological parameter space such as the one in Figure 14.1 through the power of computer learning algorithms and the application of 3D simulations of fracture mechanics to extensive experimental knapping collections of refits; 2) the need to conduct more long-term, longitudinal learning experiments with flintknapping skill across both tactical and strategic knowledge, such as Stout et al. (2015); and 3) the need to pursue more out-of-the-box experimental work such as that of Moore & Perston (2016), which experimentally limits a knapper to tactical know-how through the imposition of a random generation of strategic movements around the core during reduction. The further development of experiments along this line may allow us to use the cognitive structure of knapping skill itself to identify when strategic knowledge is required or not to produce a given lithic technology. The more such creative experimentation is shared among the research community the more likely it is that we will be able to establish when sharing of one type or another was required in our forager past.

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