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ARTICLE

Speculation Made Material: Experimental Archaeology and Maker's Knowledge

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Abstract

Experimental archaeology is often understood both as testing hypotheses about processes shaping the archaeological record and as generating tacit knowledge. Considering lithic technologies, I examine the relationship between these conceptions. Experimental archaeology is usefully understood via "maker's knowledge": archaeological experiments generate embodied know-how enabling archaeological hypotheses to be grasped and challenged, and further, well-positioning archaeologists to generate integrated interpretations. Finally, experimental archaeology involves "material speculation": the constraints and affordances of archaeologists and their materials shape productive exploration of the capacities of objects and human skill in ways relevant to archaeological questions.

1. Introduction

When philosophers discuss speculation, it is as a theoretical, imaginative activity. The generation of ideas and hypotheses is implicitly removed from the material activities of experimentation and observation.[1]

When archaeologists consider experimental archaeology, it is often in a hypothesis-testing mode: archaeologists perform experiments to probe ideas about how past processes shape the material record.

I will not deny the importance of archaeological experiments in validating theories of past processes, nor of theoretical speculation. I will highlight sins of omission. Speculation in experimental archaeology is intimately linked with the materiality of the archaeological record and proxies: it is speculation made material. Experimental archaeology provides epistemic goods beyond hypothesis-testing: it generates "maker's knowledge," which positions archaeologists to grasp, critique, and integrate archaeological knowledge.

[1] An exception being discussion of "exploratory experiments" (e.g., Franklin-Hall 2005; Currie 2020). Exploratory experiments explore a particular phenomenon generated via experimental procedure; experimental archaeology is typically geared towards understanding past practices by re-enactment. Both are exploratory, but toward differing aims.

I will provide an initial characterization of experimental archaeology, emphasizing hypothesis-testing and linking archaeological theory with the material record. I will then introduce two worries that my account of experimental archaeology will mitigate. First, Martin Bell's (2014) *Xeroxing*: instead of reconstructing objects from the material record, archaeologists sometimes reconstruct previous archaeologists' reconstructions. The second is an integrative challenge. Material analysis requires decontextualizing various excavated items. However, archaeological knowledge requires integrating, considering sites of interest holistically. How, then, do archaeologists balance the benefits of isolated analysis with the need for integrated explanation?

I respond by arguing that *maker's knowledge* captures some of experimental archaeology's epistemic features. "Maker's knowledge," a notion with deep roots in Early Modern philosophy, grants know-how a central place in epistemology: to understand something is to know how to construct it. I will provide a philosophical analysis of such knowledge, focusing on how making "well-positions" agents to gain knowledge. I will argue that maker's knowledge illuminates experimental archaeology in two ways. First, experimental practice provides archaeologists with relevant know-how for understanding relevant experimental traditions, partially mitigating Xeroxing. Second, maker's knowledge well-positions archaeologists to integrate previously decontextualized knowledge.

Finally, I will consider experimental archaeology as a material mode of speculation. I will argue that sometimes successful speculation turns on local engagement with the material at hand; speculative practices can be intimately tied to material engagement. In experimental archaeology, speculation is not decoupled from building things, breaking things, and the close examination of material. Here, speculation is best understood as an embodied practice.

I now mention a few caveats. Experimental archaeology is diverse. I will focus on lithic technology, particularly flintknapping. Despite this focus, I have not hastily generalized from cherry-picked examples. I do not argue that all experimental archaeology, nor speculation, is best understood in terms of maker's knowledge and materiality. Rather, experimental practices like flintknapping are well-understood in these terms. Further, there are discussions within archaeology that I lack the space to engage with substantively: Ingold's important work on materiality and improvisation (Ingold 2014), Renfrew and Malafouris' enactivism (Renfrew 2004; Malafouris 2007; Iliopoulos 2019), and the tradition of chaîne opératoire (Dobres 1999; Audouze and Karlin 2017). My approach differs sufficiently to leave engagement for now.

2. Experimental archaeology

The term "experimental archaeology" has various applications. Archaeologists reconstruct ancient buildings and recover ancient pottery, textile, and tool-making techniques. Lithic tools construction, my focus, is a hobby, is for museum and pedagogical purposes; towards discovering how they were made, used, and to understand their traces. These practices' history stretches to at least the 19th Century (Johnson 1978).[2] In light of this diversity, we should narrow focus and lay groundwork.

[2] For more systematic approaches to varieties of experimental archaeology, see Outram (2008) and Reynolds (1999).

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Recent discussion of experimental archaeology emphasizes hypothesis-testing and its role in "bridging" archaeological theory and the material record. Regarding the former, I will characterize experimental archaeology as "trace-based reasoning": the practice involves testing hypotheses that link the archaeological record with the past via historical processes. Regarding the latter, I will argue, we can make sense of experimental archaeology's "bridging" role by emphasizing how interaction with materials grounds archaeological interpretation. I will then isolate two challenges that my account will illuminate: "Xeroxing" and "integrative interpretation."

2.1 Hypothesis-testing

Most archaeologists spend more time collating and analyzing materials than engaging in fieldwork. These processes are sophisticated and varied: the material record is categorized, organized, and put to multiple analyses, from comparative work to various chemical and physical studies. Although this involves experiment, it is not "experimental archaeology." I will reserve that term for the practice of performing experiments towards understanding the processes that shape the material record.

In this vein, Alan Outram emphasizes "actualism": using similar materials to those used in the past to test hypotheses:

> . . . hypotheses can be tested with authentic materials and in a range of environmental conditions that aim to reflect more accurately "real life" or "actualistic" scenarios. Such experiments investigate activities that might have happened in the past using the methods and materials that would actually have been available. (Outram 2008, 2)

Dana Millson has similar emphasis:

> Experimental Archaeology thus forms an essential step in archaeological endeavour whereby hypotheses and theories that have been made about the past can be tested to be confirmed or rejected. (Millson 2011, 4)

So too does Jodi Reeves Flores:

> [experimental archaeology is] 1) the process of replicating past material culture, conditions, and/or processes in order to address a hypothesis, as well as 2) the use of products resulting from the replication of past material culture, conditions and/or processes. (Flores 2011, 41)

So, we can understand experimental archaeology in terms of *trace-based reasoning* (Currie and Killin 2019). To infer from a material object (a trace) to the past, we need to understand how past processes shaped that object: hypotheses capturing regularities about how objects are deposited, how they degrade and transform over time, and how they relate to other objects (Raab and Goodyear 1984; Kosso 1991; Jeffares 2008; Currie 2018). Archaeologists identify dependencies between traces and the past. For instance, patterns of cut-marks on bones speak to how they were butchered. Inferring

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from cut-marks to butchering techniques requires hypotheses explaining how various butchering techniques generate distinctive cut-marks.

So, to infer from a trace to the past, archaeologists need hypotheses about how historical processes shape the material record. As a first pass, we can understand experimental archaeology as the business of testing hypotheses concerning such processes. Consider Kuhn's seminal work on the morphology of lithic flint tools.

Kuhn is interested in "resharpening":

> One important aspect of the "use life" of a tool is the frequency of renewal or resharpening. The resharpening of tools is an economical tactic for producing sharp, usable edges while minimizing the cost of transporting multiple tools or bulky raw materials. (Kuhn 1990, 583)

Kuhn's index infers a tool's "reduction": how much it has been resharpened over its life. Approximately, the index is a relationship between the thickness of flaking scars and the thickness of the tool. Kuhn conducts experiments to argue that measurement data of flaking scars and thickness can be read as traces of past reduction:

> In order to ascertain the degree to which variation in flake form and measurement error affect the precision of the geometric index of reduction, 25 unifacial sidescrapers were progressively reduced and reduction indices calculated at each resharpening. In order to simulate a diverse archaeological assemblage, the sample included flakes which varied widely in form. (Kuhn 1990, 586)

This is experimental archaeology as hypothesis testing. Kuhn wants to infer from a trace—archaeological lithics—to reworking over the lithic's life. This requires a hypothesis capturing dependencies between a lithic remains' morphology and its past resharpening. The measurement index is that hypothesis quantified, and he validates it by constructing reasonable proxies of those lithics and exploring the relationship between resharpening and the flakes' subsequent morphology.

2.2 Experiment and interpretation

So, we can understand experimental archaeology via trace-based reasoning; archaeologists conduct experiments to test hypotheses about how the archaeological record forms. Some archaeologists also claim that experimental procedures aid in mitigating the so-called "subjectivity" of archaeological interpretation. I'll briefly defend this idea.

Despite its long history, experimental archaeology is often linked to the development of "new" or "processualist" archaeology in the 1960s (Binford 1962). Post-processualists argued that such approaches undervalue humanistic interpretation and hide various biases. Recently, defenders of experimental archaeology argue that it bridges the apparent dichotomy between archaeology-as-science and archaeology-as-art/craft (see Shanks and McGuire 1996). As Millson puts it:

> Theory can then be reconsidered in light of this new information and a new foundation for further study created. So, although scientific in practice,

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> Experimental Archaeology is strongly connected to theory and plays a bridging role between data and theory – between science and arts. (2011, 4)

Or as Koerner puts it, "experimental archaeology might be highly relevant for fresh orientations towards apparently irresolvable clashes between the most influentially opposed so-called 'new' and 'post-processual' theoretical paradigms" (2011, 2).

Experimental archaeology is positioned as answering a perennial archaeological challenge: pernicious forms of subjectivity arising from the lack of constraint from the material record. I think we should take Koerner and Millson's claims about experimental archaeology seriously.

The standard answer to the problem of interpretation is a combination of *multivocality* and *reflexivity* (Hodder 1999). Both multiple evidence streams and multiple perspectives are brought together in interpretation; archaeologists continually reflect on how archaeological preconceptions might shape and bias those interpretations (Gero 2007). Complementarily, Bob Chapman and Alison Wylie highlight the materiality of the archaeological record:

> [the archaeological record has] a striking capacity to function as a "network of resistances to theoretical appropriation" that routinely destabilizes settled assumptions, redirects inquiry and expands interpretive horizons in directions no one had anticipated. (Chapman and Wylie 2016, 6)

Despite the subjectivity of interpretation, archaeological reasoning from material often pushes beyond preconceptions. How? Chapman and Wylie's answer is two-pronged. First, evidential reasoning in archaeology is non-hierarchical, not relying on some bedrock of well-established theory, but on complex patterns of scaffolding. Second, this scaffolding is in continual contact with an often-intransigent material record. The objects archaeologists analyze will not bend to preconceptions anywhich-way; the material record provides a rich empirical grounding for archaeological interpretation.

So, archaeologists adopt a reflexive, pluralistic, and integrative approach to interpretation. These strategies practically resolve theoretical debates amongst archaeologists.[3] Why think experimental archaeology plays a special role? Following Chapman and Wylie, insofar as experimental archaeology ties interpretation to the record, we can understand it as bridging free-wheeling interpretation and the "network of resistance" materiality affords. It forces archaeological interpretation to be linked to, tested and formed by, their engagement with materiality.

For all that they may still be problematically reflected in archaeological attitudes and institutions, epistemically speaking, there is reason to consider the dilemmas around the subjectivity of interpretation resolved. The intransigence of the material record, a diversity of evidence streams and perspectives, and continual reflection by archaeologists themselves, allow them to navigate the tension between too-conservative mere categorization and analysis of the material record, and

[3] This is only partly true; debates sometimes concern what kinds of questions archaeologists should ask and what the point of archaeological analysis is (Currie 2019a).

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too-ungrounded speculation (Wylie 1985). And in this, by tying archaeologists further to materiality, experimental archaeology is a crucial lynchpin.

2.3 Xeroxing and integration

I have provided an initial characterization of experimental archaeology as the practice of using proxies to probe hypotheses concerning processes linking the archaeological record to the past. These practices play into how archaeologists resolve problems from the subjectivity of interpretation. But not all epistemic ducks are in a row. I will highlight two epistemic worries that my account of experimental archaeology partly mitigates. The first comes from the experimental nature of archaeological practice.

Experiments do not stand alone. They form experimental traditions: apparatus, experimental sequences, background knowledge, and best practices become codified across labs, passed through pedagogical practices, established as standardized publication requirements, and so forth (e.g., Franklin 1989). Such traditions ensure repeatability, meaningful communication between scientists, and the exploration of experimental systems. However, archaeologists are well aware of the contingency of past human societies and behaviors: across time and place, humans do things differently, sometimes dramatically so (Barrett 2016). While some archaeological knowledge may be quite general—how various materials degrade over time, say—others might be extremely local. There is a tension here between the importance of experimental traditions to archaeologists' constructing knowledge, and the unique, contingent nature of archaeological targets.[4]

Martin Bell captures this tension with "Xeroxing" (2014). Xeroxing is concerned with experimental traditions, so it is particularly pertinent to our focus. Bell targets open-air experimental archaeology, particularly the practice of constructing roundhouses, popularized in the UK by Peter Reynolds.

> Reynolds's roundhouse constructs have been highly influential – in a way, rather too much so, because many examples made by others fall into the "Xeroxing" category, whereby one experiment reproduces rather than tests the results of another. (2014, 50)

"Xeroxing" is the practice of recreating another's experiment, rather than recreating features of the site of interest. This raises two related problems. The first concerns *independence*. We can understand an inference about a particular archaeological site as drawing on two kinds of theory: (1) a particular hypothesis about the site (say, that a roundhouse was built thus-and-so), and (2) hypotheses linking traces to past processes (say, that various topographical scoops are indicative of past roundhouses). What Wylie calls "vertical independence" concerns the relationship between the evidential bases of these two kinds of hypotheses (2011). If they overlap significantly, there is a danger of evidential circularity. The second problem concerns the generalizability of archaeological knowledge. If building practices (say) are to archeological

[4] This kind of point has recently become a point of contention in ethnoarchaeology; see Gosselain (2016), Lyons David (2019).

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targets, then focusing experiments on structures from single locales might miss and misapprehend that diversity.

Xeroxing challenges any experimental tradition but is particularly pressing in archaeology because of the diversity and peculiarity of human cultural practices and products.

Against Xeroxing, Bell recommends that experimental archaeologists orient their efforts closely to the specifics of sites, rather than too-closely following pre-existing experimental practices:

> . . . there is still a tendency to interpret what we have found in terms of what others have found, rather than on the basis of detailed, empirically based work. Analogy drawn from ethnography and experiment is one of the ways in which our frame of reference and pool of ideas can be expanded. Experiments enable us to test interpretations and evaluate or limit the influence of pre-understandings. (2014, 55; see also Bell 2009)

Bell's recommendation is not unfounded. By focusing their experimental efforts more towards the specifics of sites, idiosyncrasies may shine through. However, as we will see, my account of experimental archaeology also provides grounds for a sunnier conception of Xeroxing. Let's consider archaeological integration.

Archaeological analysis involves decontextualization ("fragmentation," Jones 2002).[5] In the field, archaeologists identify, categorize and extract objects that will become archaeological data. These processes require removing objects from original placement and "carving" them from general deposition. This necessitates information-loss: extraction is destructive, and only some information about deposition and extraction can be recorded. In material analysis, particularly those involving chemical and physical properties, objects are considered in isolation, in terms of, say, rates of carbon-decay. But archaeological interpretation involves integration; sites are considered holistically from a range of perspectives and evidence-lines.

How do archaeologists integrate fragmented, decontextualized evidence? We have seen part of the answer. As Bell says, "greater independence of preunderstandings is achieved where a range of specialists from different disciplines and backgrounds contribute to interpretative debate" (46). Fragmented evidence is an opportunity for multivocality in interpretation and consilience in evidence. However, more can be said about the epistemic nature of these interpretative debates. I will argue that conceiving of experimental archaeology via maker's knowledge provides a richer answer: experimental archaeology creates know-how, which positions archaeologists to productively engage in integrative interpretation.

3. Maker's knowledge, positioning, and embodiment

We have identified two challenges for archaeological knowledge relevant to experimental archaeology: Xeroxing (experimental traditions drawing on previous experiments rather than sites themselves) and integrative interpretation (reassembling decontextualized evidence). Understanding experimental archaeology in terms of

[5] See Leonelli (2016) for more general discussion of de-contextualization.

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"maker's knowledge" sheds light on both. I'll discuss the concept generally before applying it to experimental archaeology.

I've thus-far discussed experimental archaeology as hypothesis-testing, but another common theme is its generation of expert embodied skill. Consider these reflections by François Bordes', at the time a famous skilled knapper and archaeologist:

> . . . no publication, no conference, no movie will ever replace the actual production, by the archaeologist himself, of the tools he is studying . . . [compared to skilled knappers] it was much more difficult to pass it on to the archaeologists who had never, or almost never, taken a hammerstone or an antler in their hands . . . I feel them more than I see them. (Johnson et al. 1978, 359)

Part of the aim of my analysis is to reconcile Bordes' appeal to tacit, practical knowledge with the hypothesis-testing we saw in section 2.[6] To begin, we'll need an account of maker's knowledge.

3.1 Maker's knowledge

"Maker's knowledge" connects knowledge with constructing or bringing about the subject of knowledge. The notion is often discussed in the context of Early Modern debates about knowledge's fundamental source (e.g., Gaukroger 1986; Pérez-Ramos 1988), tending towards foundationalist readings of maker's knowledge, which I will avoid here (see O'Malley 2009).

We can consider the underlying idea of maker's knowledge by comparing the epistemic standing of an agent who constructs or brings about, with that of an agent who has observational or testimonial knowledge. I will use Floridi's recent discussion (2018) as a starting point; his account is useful for providing an approach to maker's knowledge that avoids various epistemic rabbit-holes.

Floridi considers maker's knowledge via propositional information. For some proposition p, what is the difference between someone observing or being told p, and someone who has brought p about? For Floridi, the difference is not p's *content*; in principle, the same information can be had by observers and makers; p is p for either agent. Rather, the difference is in the "account" of their knowledge, their justification. Where for observers "we are talking of experience epistemically, in terms of perception," for the maker, "we are talking about experience pragmatically, in terms of interaction" (2018, 478). For Floridi, the maker's knowledge is not a posteriori, because the knowledge does not turn on makers experiencing p, but on their bringing p about. That is, "maker's knowledge is knowledge of a system from within, not from without" (Ibid, 479).

For illustration, consider some knowledge related to lithic construction: "the presence of negative scars [are] a basic characteristic of core-like things" (Hiscock 2007a, 209). Cores are rocks from which flakes are scraped during reduction. Negative scars

[6] An interesting set of analyses that parallel my own can be found in a collection edited by Cunningham, Heeb, and Paardekooper (2007). There, they distinguish between *experimental archaeology*, which more-or-less tracks hypothesis testing, and *experiential effects*, the experiences that experimental archaeology generates.

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are the remains of removed flakes.[7] On Floridi's analysis of maker's knowledge, I (who have not practiced toolmaking) can know that negative scarring is a feature of cores just as an experienced flintknapper can. However, our account of that knowledge differs. I can point to papers and observations and speak to the trustworthiness of those sources. A flintknapper reports that they have in fact struck a core to create a flake, thus bringing about the negative scarring. The flintknapper has been part of a negative-scar-producing-system.

There are at least two worries we might have about Floridi's account. First, maker's knowledge is intimately connected with tacit know-how, which is awkward for an information-theoretic account. That is, Floridi's approach is restricted to propositional knowledge (say, of the form "that *p*"), but we might think maker's knowledge can also be non-propositional, knowing how to construct a lithic for instance (e.g., Fantl 2008). If non-propositional know-how is a distinct kind of knowing, then Floridi's account is critically restricted. Second, the account relies on an in-principle distinction between the maker's observational knowledge *that they successfully brought about p* and the maker's knowledge *that p occurred*. These are intimately linked in practice; surely my knowledge that I successfully brought about *p* (which is typically observational) grounds my maker's knowledge of *p*'s occurrence. If in most circumstances maker's knowledge requires observational knowledge, we might question its importance. Happily, for our purposes, both worries can be discharged.

Floridi's account leads us to ask not whether there is a fundamental difference in the kind of knowledge makers and observers have, but after their differing accounts of knowledge. This avoids vexed questions about the relationship between know-how, know-that, and other kinds of knowledge that worried us earlier (e.g., Lewis 1988; Roland 1958). We need not ask if in principle the maker and the observer can possess the same knowledge. Instead, we ask whether making something "positions" an agent to learn *p* more efficiently.

By *positioning,* I mean a relationship between some knowledge, an agent, and a set of epistemological processes. An epistemological process *well-positions* an agent towards some knowledge just in case engaging in that process makes it more likely that the agent will learn that knowledge, compared to alternative processes. I might learn that negative scarring signals a core by reading about it, or by flintknapping. Whether testimony or making better positions depends on features of the agent, the type of knowledge at hand, and the relevant comparisons. We can ask questions about positioning regardless of whether we think all knowledge is ultimately propositional or whatever. Further, we need not follow Floridi's focus on propositional knowledge when considering positioning. I might be well-positioned to learn some skill, gain some phenomenal knowledge, and so forth. Thus, "knowledge" in positioning need not be propositional.

Positioning deflates the second objection to Floridi. This objection relied on a close connection between an agent's maker's knowledge and their a-posteriori knowledge of having successfully made something. When considering how epistemic processes position agents, we naturally combine maker's and observational knowledge, because we focus on processes of knowledge attainment. Reading a paper utilizes background

[7] There is definitional quibbling over what counts as a "core" and a "tool," which, with apologies, I will skate over.

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knowledge about subject matter and the ins-and-outs of paper reading; making a lithic tool utilizes embodied knowledge about toolmaking, checking the made product against previous examples, etc . . . . Abstract distinctions between testimonial, observational, and maker's knowledge are readily combined when considering how epistemic processes position an agent.

So, what knowledge do activities like flintknapping well-position us for? A plausible answer is *embodied knowledge of construction processes*. So, let us consider embodied knowledge.

3.2 Skill and embodied knowledge

Discussion of embodied knowledge often begins by distinguishing between two kinds of memory: *episodic* and *procedural.* The former concerns recollecting particular events; the latter is a form of know-how involved in performing actions. The flintknapper might episodically recall a disastrous flaking attempt, the vivid disappointment of an apparently promising core cracking under a mistimed strike. Procedurally, processes of expert flintknapping draw on practiced skills and embodied actions built over years of practice. There is a rich literature across philosophy and psychology on the nature and relationship between episodic and procedural memory. This work often challenges representationalism or cognitivism about the mind, typically by demonstrating how our bodily environments shape mental content (e.g, Wilson and Foglia 2017). We need not dip deeply into those waters. Jonno Sutton's discussion of expert cricket batting focuses on the processes underwriting expert skill performance, making an excellent jumping-off point for us (Sutton 2007; Richardson and Chemero 2014).

Sutton challenges the cliché that the performance of expert skill requires, as it were, not thinking about what you are doing, i.e., cutting oneself off from explicit episodic memory.

> [on such views] Having such batting skills and embodied memories, and being able to employ them, is utterly different from knowing about them, or being able to describe them, or even remembering your earlier exercise of them: practitioners differ profoundly from coaches, critics and commentators. (2007, 767–8).

Against this strict split between on-line conscious episodic memory and off-line tacit embodied skill, Sutton emphasizes their interaction:

> . . . on the intelligence of the body and the diverse forms of interaction and mutual influence—cooperative as well as competitive, harmonious as well as disruptive—between thinking and doing: accepting that habits and skills are genuinely independent of conscious thought should not blind us to the ways in which genuine expertise allows, and sometimes requires, their sculpting and shaping. (2007, 722)

For Sutton, expert skill is fundamentally reactive, involving careful adjustments, thus requiring feedback from explicit, online, and episodic cognition: "experts require their embodied routines to be continually responsive to those varying conditions,

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and thus must have learned to influence themselves. Intelligent action must be flexible . . . " (774). Experts monitor how performance proceeds, anticipating possible hiccups and required adjustments, both being "lost in the process" and aware of the space of possible outcomes.

Like cricket batting, flintknapping is a complex, dynamical skill requiring the integration of bodily-learnt habits and a probing awareness of the task's unfolding. It is "a form of regulated improvisation" as well as "a dynamic interceptive action" (2007, 764). The skilled knapper aims for a well-made tool via well-performed strikes whilst improvising around the contingencies of the core itself and the effects of previous scrapes. Although maker's knowledge often emphasizes literally building things, note that by Floridi's account (and my development of it), performance can generate maker's knowledge as well. Both in making a lithic tool and performing a well-timed sweep-shot, the agent is part of the system bringing about the source of knowledge.

So, in the context of experimental archaeological practices like flintknapping, we can understand maker's knowledge as the possession of dynamic embodied skill that integrates both habitual tacit know-how and various reactive monitoring intentional processes.

4. Redux: xeroxing and integrative interpretation

In section 2, I highlighted two challenges. First, Xeroxing, the reconstruction of previous reconstructions, rather than reconstructions of particular sites. Second, archaeological analysis decontextualizes objects from their deposition and other objects in the site: they're considered in isolation; yet archaeological analysis is integrative. In section 3, I gave an account of experimental archaeology in terms of "maker's knowledge": building lithics well-positions practitioners to generate intimate embodied knowledge of construction processes and so forth. In this section, I'll bring these together, showing how understanding experimental archaeology in terms of maker's knowledge partially mitigates Xeroxing and sheds light on integration. In brief, experimental archaeology well-positions archaeologists for embodied knowledge of processes of construction. In the context of an experimental tradition, this enables grasping and challenging various archaeological explanations, an epistemic benefit beyond hypothesis-testing. Further, embodied knowledge is a crucial tool for reintegrating previously decontextualized information.

4.1 Experimental traditions in archaeology

Bell's worries about xeroxing center on hypothesis-testing. We want to keep background theory independent of particular hypotheses; as such, reconstructing a previous reconstruction—partaking in an experimental tradition—builds the tradition's preconceptions into hypotheses. But science is not about hypothesis-testing alone. Scientists require working knowledge and understanding of the hypotheses and theories they work with.[8] This is emphasized for experimental archaeology in pedagogical and public-facing contexts (Clarkson and Shipton 2015; Torres and Márquez-Grant 2011), but I think it plays an important role for practicing scientists as well. The

[8] For recent philosophical work emphasizing understanding in science, see Potochnik (2017), De Regt (2017), and De Regt, Leonelli, and Eigner (2009).

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development of embodied knowledge of how to construct lithics, roundhouses, and so forth, well-positions archaeologists to understand the claims of previous traditions and to challenge them.

Consider the simple lithic knowledge from earlier: negative scarring signals core-like properties in a worked rock. You could grasp this by testimony and observation or by building lithics yourself. As we have seen, developing expertise involves integrating embodied tacit processes with monitoring and forward-planning as tasks unfold. Making negative scars through flintknapping is a direct way of seeing why negative scarring, and particular fine-grained properties of scarring, signals not only core-like properties, but a sense of the expertise of the knapper, why the piece was worked as it was, and so forth.

Such deep knowledge of flintknapping (or roundhouse-constructing, etc. . . .) brings three benefits. First, the archaeologist does not simply know *that* negative scarring signals a rock being core, but *why*. That is, their understanding of flintknapping processes clarifies why certain kinds of rock morphology are traces of toolmaking. This matters for understanding, say, Kuhn's foci on particular morphological characteristics in his reduction index. Logic obscure to me might be obvious to the flintknapper. Embodied knowledge well-positions archaeologists to grasp work like Kuhn's.

Second, embodied knowledge can underwrite analyses of various assemblages by using the experimental tradition to ground judgements of quality, difficulty or skill:

> Knappers can give us some idea about the difficulties involved in attaining various out-comes and also estimates of the seriousness of various errors for the knapping sequence. Following this reasoning, the number and severity of knapping errors should reflect skill in knapping performance. (Olausson 2017, 129)

Third, maker's knowledge matters for identifying how other sites buck trends and assumptions embedded within experimental traditions. For example, there are two approaches to categorizing lithics, one focusing on function, the other on processes of construction. Peter Hiscock calls the former "typology" and the latter "material" (Hiscock and Attenbrow 2003; Hiscock 2007a; the terms "morphological" versus "technological" are also sometimes used). He objects to typologies on various empirical and theoretical grounds, but the critical difference for us is in how understanding processes of reduction reveals variation across tools in terms of differences in construction processes; a discrete functional typology is transformed into a gradual picture of change.

> . . . in materialist classifications repeated artifact forms are explained by reference to activities that impinge on knapping and artifact use. Hence while typological classifications typically cite factors involving design criteria to explain the form and abundance of retouch, materialist discussions might cite mechanisms such as the rejuvenation of a dysfunctional edge, raw material properties, raw material availability, and the form of hafting. (Hiscock 2007a, 202)

Materialists examine "the form of an artifact in terms of the mechanisms by which it was created" (202). Here, maker's knowledge of the construction of artifacts leads

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archaeologists away from typological classification to "material" classification. Archaeologists in both traditions build lithics, but folks like Hiscock and Kuhn were not merely Xeroxing previous efforts.

This partially mitigates Xeroxing. Insofar as we are in the business of hypothesis-testing, following an experimental tradition can lead to circularity, obscuring the contingencies of different sites and traditions. Even if Xeroxing positions oneself to understand archaeological processes, one must go beyond it both to understand particular sites and get a broader sense of the diversity of cultural, technological, and economic practices that archaeologists are interested in. Regardless, once we consider aspects of knowledge-production beyond testing hypotheses, we see that the embodied skill experimental archaeology positions us for enables fruitful understanding of, and engagement with, experimental traditions in archaeology.

4.2 Danish daggers and integrated interpretation

Archaeologists are not primarily interested in measuring and categorizing the archaeological record: they aim to understand the lifeways and material, economic and social practices of past humans. Therefore, they develop integrative interpretations of particular sites and societies. This is why the decontextualization of material extraction, categorization and analysis presents a challenge. Maker's knowledge well-positions archaeologists for re-contextualizing. To see this, let us delve into a case study.

A vexing phenomenon in the Neolithic record is the sheer quantity of tools; there are too many, and of too high quality, for utility to explain. Archaeologists have appealed to pedagogical or economic factors or hypothesized that fancy lithics might be prestige or ritual items, or that they mark differences between casual, beginner knappers and craft specialists. Considering the phenomenon in the Northern European late-Neolithic, Deborah Olausson argues that the prevalence of flint daggers of high technical competence signals the presence of skilled (but not necessarily professional) artisans "who wished to challenge their own embodied flintknapping skills" (2017, 127). In doing so, Olausson moves beyond understanding how particular flintknapping processes work in isolation, to consider them in an integrative context: how do flint daggers fit into the complex social worlds of their makers?

Traditionally, archaeologists built relationships with skilled knappers and made inferences based on their expertise and reports. Subsequent hypotheses often reflected those knappers' circumstances, projecting into the past their high-prestige master/apprentice style hierarchies. Olausson's work is part of an ongoing discussion challenging this (e.g., Apel 2009; Apel and Knutsson 2006). She suggests that part of the motivation behind prestige-based explanations is the difficulty modern knappers have in making the best examples: "contemporary knappers regard making a 'Danish dagger' as an almost unreachable goal, shrouded in mystery" (Apel and Knutsson 2006, 133-4). But this is true only of the period's best flint daggers: there is a wide variety of quality and apparent use.

Traditionally, it is assumed that highly technical, potentially ornamental objects require structured division of labor. Olausson challenges this assumption via a quantified study of 511 flint daggers. She measures the skillfulness of a dagger's

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Figure 1. Late Neolithic Stone Daggers, from most skilled (left) to least (right) (Olausson 2017, 129, © Taylor and Francis).

construction in terms of four quantified properties: knapping errors, width-thickness ratio, symmetry, and length (Figure 1). Such quantified measures are grounded in the experience of skilled modern knappers; the justification of the skill-measurement turns on the traditions knappers have developed over years of communal practice. From the quantified study, Olausson points to the wide variety of skill within the traditional categories of flint daggers, noting there is "little variation in skill levels *between* types" (Olausson 2017, 131, emphasis hers); every style of dagger ranges between the highly skilled and the unskilled.

Olausson then builds a picture of knapping pedagogy and social structure. She estimates production levels based in part on how long it takes modern knappers to complete skilled work (as high production may indicate economic demand). The quantity of daggers that could be produced by specialized, highly skilled, fulltime knappers outruns estimates from the record. "... production volumes do not speak of mass production or dagger factories churning out large numbers of standardized products" (Olausson 2017, 133).

Pointing to the common examples of daggers made across a wide range of skill, Olausson argues that "virtually any member of Late Neolithic society was able to make a dagger, although only a few could make the finest daggers" (Ibid., 133). She compares a community of expert, institutionally supported, full-time knappers making prestige items utilizing potentially secret, protected knowledge to techniques developed by a less structured group of passionate amateurs. For illustration, she compares Marc Pfeiffer, a hobbyist cabinet maker and Errett Callahan, who "In his prime ... could be described as a full-time knapping specialist" (Ibid., 137).

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> I suggest that Marc, striving for artistic excellence and driven by a personal sense of satisfaction but not making a living at his craft, might be a better model for the makers of the finest Late Neolithic daggers. As people sharing a lithic habitus, all members of Late Neolithic society were able to knap flint at some level of skill. The poor and mediocre daggers suggest that large numbers of individuals made daggers, although with varying degrees of success. A few individuals were particularly talented and interested, and when they had time on their hands they experimented with flint. (Ibid, 137)

Regardless of whether we agree with Olausson, this is a remarkable feat of integration; we shift from understanding flint daggers as isolated, decontextualized objects, to things whose makers are embedded in social, economic, and institutional contexts. In Olausson's analysis, embodied knowledge of flintknapping does not simply generate lines of evidence, it—and the objects themselves, as I will argue—provided a crucial platform underwriting integration, grounded by maker's knowledge of modern flintknappers: their judgements about skill, the time and work it takes them to gain expertise and construct individual daggers, and their varying motivations.

Olausson's analysis relied on knappers' judgements about dagger quality. Her measurements are an approximation or distillation of that knowledge. Knapper's know-how, their embodied understanding of dagger construction, was crucial for shifting from the daggers understood as isolated artifacts to objects integrated into social worlds. Because modern knappers partake in similar embodied practices as ancient knappers (however different their social worlds), they provide a partial bridge to them. Archaeological integration requires imagining the material record as something used, built, and discarded by folks embedded in various traditions, cultures and practices, and —however obliquely—embodied knowledge is critical for such imagining.

Further, specimens themselves matter for archaeological integration: flintknapper's embodied knowledge isn't only of the processes that would produce flint daggers, but of flint daggers. In a biological context, Jim Griesemer has argued that focal organisms are sometimes crucial for integration. They provide a "platform" for posing various questions and bringing together varied methods.

> Organisms ... are themselves coherent systems of interacting, highly organized parts. They, in effect, package or bundle the problems that interest scientific researchers with others that they may not even be aware of until they are well engaged in a particular investigation. These problem packages afford opportunities as well as present challenges to researchers, who can barely solve one problem without creating interest in others because the coupling of parts and activities, processes and behaviors by organisms ... means that any observation or intervention to study one problem will have implications and consequences for phenomena concerning other problems. (Griesemer 2013, 529)

Similarly to focal organisms in biology, both specimens of ancient flint daggers and their modern proxies act as material platforms for integration and research direction. Because archaeological investigation of lithic technology is rooted to material objects, and such objects are not transparent to researchers, they form a remarkably productive focus for reaching into social and cognitive pasts. In the context of the skilled

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embodied knowledge characteristic of experimental archaeology, the platform is not simply the lithic materials, but of such materials coupled with the physiological and cognitive systems of the practitioners (and indeed perhaps a distributed system of such, due to communal practice).

No doubt, maker's knowledge is not the be-all and end-all of integration, but I think it plausible that it is often a crucial lynchpin.

A skeptic might appeal to the explicit nature of scientific knowledge. Recall the apparent tension between knappers like Bordes' appeal to tacit knowledge and recent conceptions of experimental archaeology as hypothesis-testing. One might say that insofar as knowledge is communal and intersubjective, it is not part of science per se: true scientific knowledge is explicit and propositional. I am not moved by such claims: processes of scientific pedagogy and continuity of practice ensure communication between scientists via shared embodied knowledge (Leonelli 2017). Science's intersubjectivity is not threatened by tacit knowledge. But even if you are tempted by that line of thought, my account has something to say about how the tacit becomes explicit. Let us briefly return to Sutton's discussion of embodied know-how and its relationship to propositional, episodic knowledge. Speaking of the view that good skilled performance requires experts cutting themselves off from episodic memory, he says:

> . . . [this] suggests the primacy of embodied performance, and the secondary and derivative role of thought and talk about the game, as if acquisition of explicit knowledge about batting or explicit memory of batting, for example, is an incidental by-product of skilled performance rather than a contributing factor in the exercise of that skill. (Sutton 2007, 772–3)

Sutton argues that explicit episodic memory plays a larger role in expert skill, but I emphasize a different point. To the extent that explicit knowledge can be generated from embodied performance, maker's knowledge well-positions us to build explicit propositional theories. Kuhn's development of a reduction index was grounded in maker's knowledge; Olausson's analysis of skillfulness comes from the embodied know-how of modern flint-knappers; Hiscock's appeal to "materialist" approaches to understanding lithics starts from learning how the tools were made. Even if we think scientific knowledge in only propositional (which we should not), we should nonetheless agree that maker's knowledge well-positions us to get it.

A final upshot is this: archaeological knowledge of lithic technology and the societies that produced them is not the purview of academic archaeologists alone, but also the specialists and craftspeople developing embodied expertise pertaining to that technology.[9] This feeds crucially into the speculative nature of experimental archaeology.

5. Material speculation

I have provided an account of experimental archaeology that emphasizes the role of maker's knowledge—embodied, complex skill—in grasping and challenging experimental traditions and building integrative interpretations. I want to close by using

[9] Thanks to an anonymous reviewer for this point.

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experimental archaeology as an example of *material speculation*. Speculation is the generation and exploration of ideas and hypotheses. Experimental archaeology does not only involve hypothesis testing but hypothesis generation and, as such, can be considered a speculative activity.

Philosophers of science have been surprisingly quiet when it comes to explicit discussion of speculation.[10] When it is discussed, speculation is understood roughly as a hypothesis that outruns available evidence, the justification of which lies in the fruitfulness of pursuing the hypothesis (Achinstein 2018; Swedberg 2018; Currie 2018, 287–9; Turner 2019).[11] Considering speculation's legitimacy, we often see fairly coarse distinctions: speculation has no part of science *qua* science (a view mistakenly attributed to Newton[12]); speculation should be unconstrained (a view mistakenly attributed to Feyarabend[13]); speculation is justified pragmatically (Achinstein 2018). Speculation is critical to science, and clearly, good speculation is directed and intelligent; not just anything will do. No doubt, speculation's justification is pragmatic, but more is beholden on us to say.

Another feature of philosophical consideration of speculation is its *theoretical* nature. Speculation involves the generation of ideas, the exercise of imagination and the risky exploration of abstract search-spaces. Speculation, in effect, is understood as occurring in the scientist's head. To illustrate, consider Peirce's rich work on "guessing" (apologies to Peirce scholars!). Peirce argues that guessing is critically important for science, roughly speaking, generating ideas that may form the basis of testable hypotheses. His advice in this regard is often psychological, recommending that good guessers should be "in as passive and receptive a state" as possible (Peirce 1929, 285). Or consider Whewell's "happy thoughts" (sorry Whewell scholars!), which are later made explicit and prepared for empirical study (Whewell 1840/1996). Again, focus is on the imaginative capacities of well-prepared minds. By contrast, speculation in experimental archaeology is sometimes embodied; the archaeologist speculates by learning and performing a complex expert skill, and their exploration is constrained and directed by their materials.

Here, speculation is "material" in two senses. First, we understand the justification of speculation by analogy with Norton's "material theory of induction." Norton argues that induction is not justified by abstract schema but by the local, material conditions (2003, ms). Norton notes that various approaches to understanding evidence, such as qualitative analyses of evidential support, quantitative (Bayesian for instance) approaches, etc., appear to work better in some cases than others. The explanation, he claims, is that facts about local conditions differently enable those accounts to gain traction:

[10] Although speculation matters a lot in, for instance, Feyarabend's epistemic anarchy, Kuhn's revolutionary science, etc. . . . Speculation is not often explicitly discussed, but much attention has been paid to scientific *discovery* (Schickore 2018). I leave connections for later work.

[11] Popper's notion of a "bold hypothesis" does not fit this mold insofar as he is focused on deductive models of scientific reasoning but is nonetheless similar in spirit.

[12] See Walsh (2019).

[13] See Kidd (2011).

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> . . . the application of the various approaches work when we add factual conditions that limit the domain in which they are to be applied. The stronger the factual restriction, the more successful the application. The material approach simply asks us to "take the limit." That is, what warrants the successful application of the particular inference is found entirely in the background factual conditions that delimit the domain of application. (Norton 2021, 4)

As for induction, so for speculation; justification is grounded in the particular material affordances scientists face. For comparison, let us use Popper as a foil (Popper 1959/2002). Popper argues that scientists should aim for maximally "bold" hypotheses: that is, hypotheses which are (1) maximally falsifiable, and (2) conflict with our current knowledge. The falsifiability of a hypothesis is an intensional notion: a hypothesis is more falsifiable to the extent that there are possible observations that would falsify it. To determine the boldness of a hypothesis, then, we need not know anything much about context beyond current going theories. Now consider flintknapping; what makes the practice of contemporary archaeologists and hobbyists spending hours figuring out how to make archaic tools so extraordinarily fruitful and productive? That is, what makes it a good speculative practice? To answer this question (I claim), we must point to the material situation archaeologists are in.

Faced with a fragmentary lithic record, and despite enormous disparity in social life, modern archaeologists and ancient flintknappers share relevantly similar materials and physiologies. Archaeologists explore the capacities of flints and other materials, discovering how to make similar tools, learning along the way the capacities of various materials and techniques and their own limitations and potential abilities. This enables archaeologists to generate diverse hypotheses and embodied knowledge, which, as we have seen, form the basis of rich, well-founded interpretations. It is the material facts that underwrite the speculation's success, not abstract properties such as a hypothesis' falsifiability. The hypotheses generated are built from and are embedded within background knowledge; they are not better because they dramatically conflict with existing knowledge as Popper would have it, although they may sometimes do so.

An anonymous referee insightfully notes that I have largely focused on what we might call the *over*generation of hypotheses; given the wide range of possible hypotheses, how do we productively narrow our search? But the inverse—the *under*generation of hypotheses—is also worthy of concern. Given the temporal distance between archaeologists and past practices, and our species' characteristic plasticity, heterogeneity, and creativity, what reason is there to think that the hypotheses we generate on the basis of our current understanding are actually relevant to the cultural past? Successfully constructing a Danish dagger establishes a *capacity* for such a thing to be built in that manner, but it does not establish that it was built the same way in the past.[14] More pertinently, how do we know that our search space is *wide enough* not to

[14] Although it is likely that the constraints on building such items are so strict that it is unlikely they could be built in another manner.

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miss relevant hypotheses?[15] Here too, the materiality of experimental archaeology provides part of the answer. The material continuity between past bodies, cognition, capacities, and objects and those employed in experimental archaeology grounds the latter's relevance for the former. Our species is diverse, but not *that* diverse. Further, the integrative and exploratory approach of archaeology can often identify where discontinuities might matter, as we saw in Olausson's arguments against projecting the specialized, hierarchical apprentice model of modern knappers into the past. At base, I think, concern for the undergeneration of hypotheses should lead us towards more diverse experimental practices in archaeology,[16] and to what extent archaeologists successfully navigate both the under- and overgeneration of hypotheses remains an open question.

Regardless, the justification of the speculative side of experimental archaeology is material.

The second sense of "material" is literal; instead of a theoretical, purely imaginative activity, experimental archaeology is speculation as a material practice: an embodied, practical activity.[17] Let us briefly consider a fairly wide-spread approach to the generation of ideas. In studies of creativity, it is common to imagine problem-solvers exploring a search-space of possible solutions.[18] Given features of the search-space, and the capacities of agents, how ought problem solvers explore? Are there systematic, methodical approaches that increase the efficiency of discovering good solutions? One tactic narrows the search space's perimeters: if we have reason to think good solutions lie in a particular area, then to an extent, our search should focus on those locations.

Following this abstract treatment, a fundamental way that archaeologists narrow their search-space is via the material conditions exhibited by experiment. The search space is set by the materials—rocks—as well as the physiology and learning capacities of the knapper. These materials shape how the knapper explores the possibility of what can be achieved, and thus the hypotheses that are explored and generated. The knappers are exploring a space of material capacities. They do not simply learn by trial and error but draw and build upon years of habit and skillful improvisation. These material capacities are intimately connected with questions about the archaeological record and are a rich source for developing testable hypotheses. Indeed, the material affordances of a knapper differ from those relying on testimony; they thus likely well-position us for learning different kinds of knowledge.

Consider once more the difficulty of constructing a "Danish dagger." In figuring out how to construct such a dagger, identifying the required skills, sequences, and

[15] In an archaeological context, discussion of this point has often focused on the pitfalls of ethnographic analogy in constraining hypotheses about the past. Given the diversity of human lifeways, why think that the current (or at least very recent) ethnographic record captures the range of possibilities? (see Freeman 1968; Gould 1980; and Hiscock 2007b for versions of this worry and see Wylie 1985, 1988; Currie 2016; and Nyrup 2020 for replies).

[16] For instance, the referee points to Tuominen's (2020) study of the relationship between dance and archaeological practice. Given that the search-space of archaeological speculation is generated by the materials and those interacting with them, varied kinds of interactors are likely to generate quite different, and potentially highly productive, search-spaces.

[17] There has been recent work on the scientific imagination, although it is more interested in analysis and modeling than explicitly its role in speculation; see, for instance, Levy and Godfrey-Smith (2019).

[18] See, for instance, Gopnik et al. (2017), Boden (2004), Currie (2019b).

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materials, modern flintknappers map out a problem space. This problem space is not set by abstract criteria, but by material circumstance. These circumstances position knappers to explore the capacities of their materials, as well as their own physiology and potential expertise, towards figuring out how to make a Danish dagger. This is as much a speculative activity as, say, the imaginative generation of a "happy thought." But that activity is fundamentally embodied and grounded in maker's knowledge.

Bringing both senses of materiality together, the material conditions of experimental archaeology afford archaeologists the capacity to explore relevant search-spaces, thus productive idea-generation; therein lies its justification. Speculation is here embodied; not purely imaginative nor abstract. Speculation is justified materially, not based on some logic of discovery.

Just as appealing to factors beyond hypothesis-testing does not deny the importance of testing hypotheses, appeal to speculation's materiality does not entail that abstract imaginings are unimportant. But it does lead to considering speculation in material terms; instead of asking about how ideas are generated in the disembodied scientific mind, we ask how the various affordances of scientists embedded in rich material and social environments lead them to explore particular capacities.

6. Conclusion

In this paper, I have provided a philosophical account of experimental archaeology, at least as it pertains to lithic technologies. In section 2, I analyzed the hypothesis-testing side of experimental archaeology, particularly as a kind of "trace-based reasoning" that aims to understand processes linking the material record to the past. I argued that, so understood, the materiality of experimental archaeology can act as a bridge between theory and practice, and then set out two further worries: xeroxing and integration. In section 3, I provided an account of "maker's knowledge" based on how bringing something about might "well-position" an agent to gain some knowledge. I then argued that experimental archaeology can be understood as well-positioning agents to gain skilled, embodied knowledge of production practices (of lithics, for example). These points were drawn on in section 4 to argue that, understood thusly, experimental archaeology mitigates and explains the role of Xeroxing in experimental traditions and how archaeologists construct integrative interpretations. Finally, in section 5, I argued that experimental archaeology is an example of *material speculation*; that is, its justification is grounded in material circumstance, and the speculative search-space is set by the physical system.

I hope to have provided fodder for those with both archaeological and philosophical leanings. For archaeologists, I have emphasized that some practices within experimental archaeology are fruitfully understood in ways beyond hypothesis-testing. Experimental practices such as flintknapping generate embodied maker's knowledge, which provision diverse epistemic benefits. Experimental archaeology is a speculative strategy where the physicality of the materials and experimenters produce fruitful exploration of the capacities required to make sense of past human activities. For philosophers, I have provided a way of understanding maker's knowledge in terms of positioning, thus side-stepping discussions of the fundamental relationship between propositional knowledge and know-how. I have shown how maker's knowledge, thus understood, is revelatory of the justification and nature of speculative strategies in science.

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My discussion has been importantly restricted in at least two ways. First, I have not provided anything like a systematic survey of experimental archaeology. Whether my characterization applies more widely is an open question. Second and similarly, the extent to which my emphasis on speculation's materiality in lithic flintknapping is revelatory of speculation in general is also an open question. These are features, not bugs; my account succeeds to the extent that it can act as a model for comparisons or contrasts across archaeological (and other scientific) practices. It may be that sometimes speculation's materiality is critical for understanding its epistemic properties, while playing a less important role in other contexts. Regardless, the embodied practices of some experimental archaeologists are a powerful example of how scientists engage with the materiality of their subjects in remarkably creative, productive ways.

References

Achinstein, Peter. 2018. *Speculation: Within and About science*. Oxford: Oxford University Press.

Apel, Jan. 2008. "Knowledge, Know-how and Raw Material - The Production of Late Neolithic Flint Daggers in Scandinavia." *Journal of Archaeological Method and Theory* 15 (1):91–111.

Apel, Jan, and Kiel Knutsson, eds. 2006. "Skilled Production and Social Reproduction. Aspects of Traditional Stone-tool Technologies." *Proceedings of a Symposium in Uppsala, August 20–24, 2003, Stone Studies 2*. Uppsala: Societas Archaeologica Upsaliensis and the Department of Archaeology and Ancient History, Uppsala University.

Levy, Arnon, and Peter Godfrey-Smith, eds. 2019. *The Scientific Imagination*. Oxford: Oxford University Press.

Audouze, Françoise, and Claudine Karlin. 2017. « La chaîne opératoire a 70 ans: qu'en ont fait les préhistoriens français. » *Journal of Lithic Studies* 4 (2):5–73.

Barrett, James C. 2016. "Archaeology After Interpretation. Returning Humanity to Archaeological Theory." *Archaeological Dialogues* 23 (2):133–7.

Bell, Martin. 2009. "Experimental archaeology: changing science agendas and perceptual perspectives." In *Landscape and People,* edited by M. J. Allen, N. Sharples, and T. O'Connor, 31–45. Oxford: Oxbow/ Prehistoric Society.

Bell, Martin. 2014. "Experimental Archaeology at the Crossroads." *Material Evidence: Learning from Archaeological Practice* 42.

Binford, Lewis R. 1962. "Archaeology as anthropology." *American Antiquity* 28 (2):217–25.

Boden, Margaret A. 2004. *The Creative Mind: Myths and Mechanisms*. London: Psychology Press.

Chapman, Robert, and Alison Wylie. 2016. "*Evidential Reasoning in Archaeology*." London: Bloomsbury Publishing.

Clarkson, Chris, and Ceri Shipton. 2015. "Teaching Ancient Technology Using "Hands-on" Learning and Experimental Archaeology." *Ethnoarchaeology* 7 (2):157–72.

Currie, Adrian. 2016. "Ethnographic Analogy, the Comparative Method, and Archaeological Special Pleading." *Studies in History and Philosophy of Science Part A* 55:84–94.

Currie, Adrian. 2018. *Rock, Bone, and Ruin: An Optimist's Guide to The Historical Sciences*. Cambridge, MA: MIT Press.

Currie, Adrian. 2019a. *Scientific Knowledge and the Deep Past: History Matters*. Cambridge: Cambridge University Press.

Currie, Adrian. 2019b. "Existential Risk, Creativity and Well-Adapted Science." *Studies in History and Philosophy of Science Part A* 76:39–48.

Currie, Adrian. 2020. "Bottled Understanding: The Role of Lab Work in Ecology." *The British Journal for the Philosophy of Science* 71 (3):905–32.

Currie, Adrian, and Anton Killin. 2019. "From Things to Thinking: Cognitive Archaeology." *Mind and Language* 34 (2):263–79.

De Regt, Henk W. 2017. *Understanding Scientific Understanding*. Oxford: Oxford University Press.

De Regt, Henk W., Sabina Leonelli, and Kai Eigner, eds. 2009. *Scientific Understanding: Philosophical Perspectives*. Pittsburgh: University of Pittsburgh Press.

Dobres, Marcia-Anne. 1999. "Technology's Links and Chaînes: the Processual Unfolding of Technique and Technician." *The Social Dynamics of Technology: Practice, Politics, and World Views*, 124–46.

https://doi.org/10.1017/psa.2021.31 Published online by Cambridge University Press

Fantl, Jeremy. 2008. "Knowing-How and Knowing-That." *Philosophy Compass* 3 (3):451–70.
Flores, Jodi-Reeves. 2011. "Creating a History of Experimental Archaeology." In *Experimentation and Interpretation: The Use of Experimental Archaeology in the Study of the Past*, edited by Dana C. E. Millson, 29–45. Oxford: Oxbow Books.
Floridi, Luciano. 2018. "What a Maker's Knowledge Could Be." *Synthese* 195 (1):465–81.
Franklin, Allen. 1989. *The Neglect of Experiment*. Cambridge: Cambridge University Press.
Franklin-Hall, Laura. 2005. "Exploratory Experiments." *Philosophy of Science* 72 (5):888–99.
Freeman, Leslie G. 1968. "A Theoretical Framework for Interpreting Archaeological Materials." *In Man the Hunter*, edited by R. B Lee and I. DeVore, 262–7. Chicago: Aldine.
Gaukroger, Stephen. 1986. "Vico and the Maker's Knowledge Principle." *History of Philosophy Quarterly* 3 (1):29–44.
Gero, Joan M. 2007. "Honoring Ambiguity/Problematizing Certitude." *Journal of Archaeological Method and Theory* 14 (3):311–27.
Gopnik, Alison, Shaun O'Grady, Christopher G. Lucas, Thomas L. Griffiths, Adrianne Wente, Sophie Bridgers, and Ronald E. Dahl. 2017. "Changes in Cognitive Flexibility and Hypothesis Search Across Human Life History from Childhood to Adolescence to Adulthood." *Proceedings of the National Academy of Sciences* 114 (30):7892–99.
Gosselain, Olivier P. 2016. "To Hell with Ethnoarchaeology!" *Archaeological Dialogues* 23 (2):215.
Gould, Richard. 1980. *Living Archaeology*. Cambridge: Cambridge University Press.
Griesemer, James. 2013. "Integration of Approaches in David Wake's Model-Taxon Research Platform for Evolutionary Morphology." *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences* 44 (4):525–36.
Hiscock, Peter. 2007a. "Looking the Other Way: A Materialist/Technological Approach to Classifying Tools and Implements, Cores and Retouched Flakes. In *Tools Versus Cores?" Alternative Approaches to Stone Tool Analysis*, edited by Shannon P. McPherron 198–222, Newcastle: Cambridge Scholars Publishing.
Hiscock, Peter. 2007b. *Archaeology of Ancient Australia*. London: Routledge.
Hiscock, Peter, and Val Attenbrow. 2003. "Early Australian Implement Variation: A Reduction Model." *Journal of Archaeological Science* 30 (2):239–49.
Hodder, Ian. 1999. *The Archaeological Process*. Oxford: Blackwell.
Iliopoulos, Antonis. 2019. "Material Engagement Theory and its Philosophical Ties to Pragmatism". *Phenomenology and the Cognitive Sciences* 18 (1):39–63.
Ingold, T. 2014. "The Creativity of Undergoing." *Pragmatics & Cognition* 22 (1):124–39.
Jeffares, Ben. 2008. "Testing times: Regularities in the Historical Sciences." *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences* 39 (4): 469–75.
Johnson, L. *Lewis.* 1978. "A History of Flint-knapping Experimentation, 1838-1976 [and comments and reply]." *Current Anthropology* 19 (2):337–72.
Jones, Andrew. 2002. *Archaeological Theory and Scientific Practice*. Cambridge: Cambridge University Press.
Kidd, Ian J. 2011. "Rethinking Feyerabend: the 'Worst Enemy of Science'?" *PLoS biology* 9 (10):1–3.
Koerner, Stephanie. 2011. "Experimental Archaeology after Simplicity–Implications for Reflexivity of Insights that a 'Common World' is not 'Given.'" In *Experimentation and Interpretation*, edited by Dana C. E. Millson, 61–95. Oxford: Oxbow Books.
Kosso, Peter. 1991. "Method in Archaeology: Middle-range Theory as Hermeneutics." *American Antiquity* 56 (4):621–7.
Kuhn, Stephen L. 1990. "A geometric Index of Reduction for Unifacial Stone Tools." *Journal of Archaeological Science* 17 (5):583–93.
Leonelli, Sabina. 2016. *Data-centric Biology: A Philosophical Study*. Chicago: University of Chicago Press.
Lewis, David. 1988. "What Experience Teaches." *Proceedings of the Russellian Society* 13:29–35.
Lyons, Diane, and Nicholas David. 2019. "To hell with ethnoarchaeology . . . and back!" *Ethnoarchaeology* 11 (2):99-–33.
Malafouris, Lambros. 2009. "Before and Beyond Representation: Towards an Enactive Conception of the Palaeolithic Image." In *Image and Imagination: A Global History of Figurative Representation,* edited by C. Renfrew and I. Morley, 289–302. Cambridge: McDonald Institute for Archaeological Research.
Millson, Dana C., ed. 2011. *Experimentation and Interpretation: the Use of Experimental Archaeology in the Study of the Past*. Oxford: Oxbow Books.
Norton, John D. 2003. "A Material Theory of Induction." *Philosophy of Science* 70 (4):647–70.
Norton, John D. 2021. *The Material Theory of Induction.* Calgary: University of Calgary Press.

https://doi.org/10.1017/psa.2021.31 Published online by Cambridge University Press

Nyrup, Rune. 2020. "Three Uses of Analogy: A Philosophical View of the Archaeologist's Toolbox." In *Interarchaeologia 6: Archaeology and Analogy*, edited by Marko Marila, Marja Ahola, Kristiina Mannermaa, and Mika Lavento, 12–31. Published by the Department of Cultures, University of Helsinki.

O'Malley, Maureen A. 2009. "Making Knowledge in Synthetic Biology: Design Meets Kludge." *Biological Theory* 4 (4):378–89.

Olausson, Dana. 2017. "Knapping Skill and Craft Specialization in Late Neolithic Flint Daggers." *Lithic Technology* 42 (4):127–39.

Outram, Alan K. 2008. "Introduction to Experimental Archaeology." *World Archaeology* 40 (1):1–6.

Peirce, Charles S. 1929. "Guessing." *The Hound and Horn* 2 (3 Spring):267–85.

Pérez-Ramos, Antonio. 1988. *Francis Bacon's Idea of Science and the Maker's Knowledge Tradition*. Oxford: Oxford University Press.

Popper, Karl. 1959/2002. *The Logic of Scientific Discovery*. New York, NY: Routledge Classics.

Potochnik, Angela. 2017. *Idealization and the Aims of Science*. Chicago: University of Chicago Press.

Raab, L. Mark., and Albert C. Goodyear. 1984. "Middle-range Theory in Archaeology: A Critical Review of Origins and Applications." *American Antiquity* 49 (2):255–68.

Renfrew, Colin. 2004. "Towards a Theory of Material Engagement." In *Rethinking Materiality: The Engagement of Mind with the Material World*, edited by E. DeMarrais, C. Gosden, and C. Renfrew, 23–32. Cambridge: McDonald Institute for Archaeological Research.

Reynolds, Peter. 1999. "Butser Ancient Farm, Hampshire, UK." In *The Constructed Past. Experimental Archaeology, Education and the Public*, edited by Philippe Planel and Peter G. Stone, 124–35. London: Routledge.

Richardson, Michael J., and Antony Chemero. 2014. "Complex Dynamical Systems and Embodiment." In *The Routledge Handbook of Embodied Cognition*, edited by Lawrence Shapiro, 39–50. London: Routledge.

Roland, Jane. 1958. "On "Knowing How" and "Knowing That."" *The Philosophical Review* 67 (3):379–88.

Schickore, Jutta. 2018. "Scientific Discovery." *The Stanford Encyclopedia of Philosophy* (Summer 2018 Edition), edited by Edward N. Zalta, https://plato.stanford.edu/archives/sum2018/entries/scientific-discovery/.

Shanks, Michael, and Randal H. McGuire. 1996. "The Craft of Archaeology." *American Antiquity* 61: 75–88

Sutton, John. 2007. "Batting, Habit and Memory: The Embodied Mind and the Nature of Skill." *Sport in Society* 10 (5):763–86.

Swedberg, Rirchard. 2018. "Does Speculation Belong in Social Science Research?" *Sociological Methods and Research* 50 (1):45–74.

Torres, Sergio M., and Nicholas Márquez-Grant. 2011. "Forty Years of Archaeology for Children." *AP: Online Journal in Public Archaeology* (1):29–44.

Tuominen, Suvi. 2020. "Sensing Within: Somatic Practice and Archaeological Objects." In *Interarchaeologia 6: Archaeology and Analogy*, edited by Marko Marila, Marja Ahola, Kristiina Mannermaa, and Mika Lavento, 135–44. Published by the Department of Cultures, University of Helsinki.

Turner, Derek. 2019. "Speculation in the Historical Sciences." *Philosophy, Theory, and Practice in Biology* 11.

Walsh, Kirsten. 2019. "Newton's Scaffolding: the Instrumental Roles of his Optical Hypotheses." In *Experiment, Speculation and Religion in Early Modern Philosophy*, edited by Alberto Vanzo and Peter R. Anstey, 125–7. London: Routledge.

Whewell, William. 1996 [1840]. *The Philosophy of the Inductive Sciences (Volume II).* London: Routledge/Thoemmes.

Wilson, Robert A., and Lucia Foglia. 2017. "Embodied Cognition." In *The Stanford Encyclopedia of Philosophy*, edited by Edward N. Zalta. https://plato.stanford.edu/archives/spr2017/entries/embodied-cognition.

Wylie, Alison. 1985. "The Reaction Against Analogy." In *Advances in Archaeological Method and Theory*, 63–111. New York: Academic Press.

Wylie, Alison. 1988. "'Simple' Analogy and the Role of Relevance Asumptions: Implications of Archaeological Practice." *International Studies in the Philosophy of Science* 2:134–50.

Wylie, Alison. 2011. "Critical distance: Stabilising Evidential Claims in Archaeology." In *Evidence, Inference and Enquiry*, edited by P. Dawid, W. Twining, and M. Vasilaki, 371–94. Oxford: Oxford University Press/British Academy.

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