



Learning through the hand: tacit knowledge, material sensitivity, and apprenticeship in Yixing Zisha teapot crafting

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Abstract

This paper examines Yixing Zisha teapot crafting as a case study of tacit knowing in traditional craftsmanship. Drawing on short-term participant observation and scholarship on tacit knowledge, embodied practice, material engagement, and skilled perception, it analyzes tactile judgment, perceptual-aesthetic evaluation, bodily coordination, and temporal sensitivity. Rather than treating these as separate forms of hidden knowledge, the paper conceptualizes them as interdependent capacities operating through perceptual attunement, situated judgment, adaptive action, and material feedback. It further proposes that some judgments may be history-sensitive because the practical significance of present material conditions may depend partly on preceding handling and change. Apprenticeship is accordingly understood as attention calibration through which learners become sensitive to action-relevant differences in resistance, moisture, balance, rhythm, and form. This process-oriented account explains why documentation may preserve procedures and observable features without reproducing the embodied capacity to interpret changing conditions and respond appropriately. The framework further suggests that artisan judgment remains consequential where material heterogeneity and process history produce variation that cannot be captured economically through standardization or current-state measurements, while identifying possibilities for hybrid systems combining standardized production with situated human or adaptive intervention. The study therefore shifts attention from documenting craft knowledge toward sustaining the social and material conditions through which tacit knowing develops and is transmitted.

Keywords

Tacit knowledge, Embodied cognition, Skilled perception, Material history, History-dependent systems, Craftsmanship, Apprenticeship, Perception–action coupling, Intangible cultural heritage, Yixing Zisha

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1. Introduction

In a workshop in Yixing, a craftsman carefully adjusts the thickness of the walls of the Zisha pot by subtle variations in hand pressure. Without the help of any measurement tools, he can feel the subtle differences in the density and moisture of the clay. Such subtle differences are hard for the eyes to observe clearly, but they can affect the likelihood of cracking during firing as well as the functional performance of the finished teapot. When asked how such judgements are made, explanations are rarely reducible to a simple calculation and often refer instead to “feeling”. Such judgments raise a more specific question than whether craft knowledge can be verbalized: what enables an experienced artisan to recognize the significance of changing material conditions and respond appropriately when no single measurement or instruction determines what should be done next?

Yixing Zisha teapot crafting, a craft tradition with roots in the Ming dynasty, provides a compelling context for the exploration of this question. While widely valued for its aesthetic and cultural significance, the process of crafting Zisha teapots reveals how knowledge is embedded in action. Compared with production settings in which standardized measurements and explicit procedures play a larger role, the Zisha practices examined here place substantial emphasis on continuous interaction between crafter and material. The crafter must judge the clay not as a fixed substance, but as a dynamic material whose moisture, resistance, geometry,

and workability change throughout the process. More importantly, the practical significance of these cues depends on their relation to the current material state, the intended action, and the transformations produced by previous actions. In this sense, skilled craftsmanship depends not only on sensing material properties, but on perceiving what those properties mean for action in a particular situation.

Tacit knowledge has conventionally been understood as knowledge that cannot be fully expressed or reduced to explicit rules (1,2). However, treating tacitness primarily as a problem of verbal expression leaves an important theoretical question unresolved: why does skilled performance remain difficult to reproduce even when substantial information about a practice can be documented? Recent work has conceptualized tacit knowing as embodied and task-specific, emphasizing how skilled performers develop bodily forms of awareness and responsiveness through sustained engagement with particular activities (3). These perspectives collectively shift attention from tacit knowledge as an inaccessible body of information toward tacit knowing as an embodied capacity enacted in skilled practice. Ecological accounts of skilled action similarly suggest that expertise involves becoming selectively responsive to possibilities for action within concrete sociomaterial situations rather than processing isolated environmental properties independently (4,5). From this perspective, the relevant problem is not simply

whether individual cues such as moisture, resistance, thickness, or temperature can be recorded. Nor is the problem simply the number of variables involved. What matters is that these cues are interdependent and that their relevance changes with the practitioner's prior knowledge, the evolving material state, and the action currently being attempted. It is how practitioners learn to recognize which relations among such cues matter at a particular moment and what those relations call for them to do.

A further question, however, concerns whether skilled judgment is determined by the material's present condition alone. In materials that undergo repeated drying, resting, compression, or deformation, apparently similar present conditions may arise through different histories of handling and change. Research on clay and other thixotropic materials shows that rheological or mechanical behavior can be influenced by prior remoulding, rest, aging, and shear history, partly through continuing microstructural reorganization (6,7). This does not establish that Zisha clay behaves in the same way under craft conditions. It does, however, raise a theoretically relevant possibility: artisans may sometimes respond not only to what the material is 'like' at a given moment, but also to how it has arrived at that condition. Tacit knowing may therefore involve sensitivity to material history as well as sensitivity to the relations among currently perceptible cues.

This paper therefore asks: How is tacit knowing

enacted through the interaction of perception, judgment, and action in Yixing Zisha teapot crafting, and to what extent might skilled judgment be sensitive not only to the material's present condition but also to the history through which that condition has emerged?

1.1 Summary

The paper argues that Zisha craftsmanship is best understood as a situated and relational form of knowing in which perceptual attunement, practical judgment, bodily action, and material response remain closely coupled. It further develops the hypothesis that some skilled judgments may be history-sensitive: the significance of a present material condition may depend partly on the preceding processes of handling, deformation, drying, resting, or adjustment. This claim is proposed as a theoretically motivated extension of the present qualitative evidence rather than as an experimentally demonstrated property of Zisha clay or cognition.

This paper makes three contributions. First, it provides an exploratory, field-based account of Yixing Zisha teapot crafting as a concrete case for studying tacit knowledge in traditional craftsmanship. Second, it develops a multidimensional account of tacit knowing in which tactile, perceptual-aesthetic, bodily, and temporal capacities operate relationally, and it extends this account by proposing that situated judgment may also be sensitive to the material history through which present conditions

emerge. Third, it develops a process-based explanation for both the limitations of codification and the importance of apprenticeship. Documentation can represent material properties, procedures, and observable actions, but representation alone does not reproduce the learned capacity to identify action-relevant relationships in changing situations. Moreover, because skilled action itself generates new sensory information, the relevant context is continually reshaped through ongoing perception–action interaction rather than presented to the practitioner as a fixed set of inputs (8). Apprenticeship is therefore conceptualized as a process of attention calibration through which practitioners gradually learn what to notice, how to discriminate relevant material differences, and how to adapt action accordingly.

2. Methods

This study adopted a qualitative case-study approach based on short-term participant observation in a traditional Zisha workshop in Yixing, China. During a two-day field study, several stages of teapot crafting were observed, including clay preparation, slab flattening, preliminary body shaping, surface adjustment, and the attachment of components. The fieldwork also included limited participation in basic tasks such as flattening clay slabs and preliminary shaping. Although this participation was limited, it provided first-hand experiential insight into the difficulty of controlling pressure, timing, and form.

The researcher's position as a novice learner provided a useful contrast between verbal instruction and successful skilled performance. Verbal instructions such as “applying moderate pressure” and “waiting until the clay is ready” did not automatically translate into successful actions during novice participation. The resulting gap between instruction and successful performance served as a case-based point of departure for examining perceptual discrimination, situated judgment, and adaptive adjustment.

The analysis drew on field notes, direct observation, and informal conversations with artisans, supplemented by secondary scholarship on tacit knowledge, craft practice, and cultural heritage. The conversations with artisans were conducted in Chinese and subsequently translated into English. Quoted remarks were used as illustrative qualitative examples of how artisans described and interpreted their practice, rather than as evidence intended to establish statistical representativeness.

This study has clear limitations. The fieldwork lasted only two days and focused on one workshop environment; therefore, the paper does not claim to represent all Zisha artisans or all forms of contemporary Zisha production. However, it offers a focused exploratory analysis of how tacit knowledge can be observed in one situated craft-learning context. Its purpose is not statistical generalization, but theoretical interpretation of a specific case. Accordingly,

claims concerning Zisha craftsmanship are interpreted as case-based theoretical propositions rather than as population-level generalizations about all artisans or workshop traditions. The analysis rests on the assumption that observed differences between novice and experienced performance can provide case-based evidence for examining situated tacit knowing, although they cannot establish how such capacities develop across the broader population of Zisha artisans. In addition, interpretations of relational or concurrent judgment are theoretical inferences from observed practice and relevant scholarship rather than direct measurements of practitioners' cognitive processes. The same qualification applies to the proposed history sensitivity of temporal judgment. The present observations show that artisans respond to material conditions developing through sequential interaction, but they do not establish whether prior history contributes independently to judgment once the material's current internal state is fully specified. History-sensitive judgment is therefore treated as a theoretically informed interpretation and a hypothesis for further investigation rather than as a directly demonstrated cognitive or material mechanism. The discussion of apprenticeship as perceptual calibration should therefore be read as an interpretive proposition supported by the case and existing literature, rather than as a longitudinally demonstrated account of skill acquisition.

3. Theoretical framework: from tacit

knowledge to situated tacit knowing

3.1 From hidden knowledge to embodied, situated knowing

Tacit knowledge has been widely discussed as a form of knowing that cannot be fully captured through explicit descriptions, formal rules, or symbolic representations. Polanyi's (1) influential distinction between focal and subsidiary awareness provides a foundational explanation for this phenomenon. According to Polanyi, skilled performance depends on the integration of numerous subsidiary elements that guide action without necessarily becoming the explicit focus of attention. The artisan who recognizes whether clay is ready for shaping, for example, may rely on subtle variations in resistance, texture, and bodily sensation without consciously separating each individual cue during the judgment process.

However, understanding tacit knowledge merely as knowledge that remains difficult to verbalize risks reducing tacitness to a problem of incomplete expression. Subsequent research has emphasized that tacit knowledge is not simply hidden information waiting to be articulated, but is embedded in practices, bodily abilities, and socially situated activities (2,9). Collins (2) demonstrated that different forms of tacitness emerge from embodied skills, collective practices, and social contexts, suggesting that some aspects of knowing are inseparable from participation in particular forms of activity. Similarly, Tsoukas (9) argued that tacit and

explicit knowledge should not be treated as independent knowledge objects, because explicit statements acquire meaning only within the practical contexts in which they are applied.

Recent research has further developed this practice-based understanding by examining how tacit knowing is acquired through embodied engagement. Hadjimichael et al. (3) argued that tacit knowledge acquisition involves the development of task-specific bodily awareness, through which practitioners gradually become capable of responding fluently to the demands of a particular activity. From this perspective, tacit knowing is not a static possession accumulated by experts, but an embodied capability enacted through skilled performance. Expertise therefore emerges through the refinement of perception, action, and responsiveness within specific practice environments.

This perspective is particularly relevant to craftsmanship, where practitioners rarely apply fixed rules to predetermined situations. Instead, they continuously interpret changing material conditions and adjust their actions accordingly. Accordingly, this study conceptualizes tacit knowing not as inaccessible information stored within individuals, but as an embodied and situated capability through which practitioners perceive meaningful differences, generate judgments, and adapt actions during ongoing engagement with materials.

3.2 Perceptual attunement and situated judgment
Skilled performance does not simply result from the ability to perceive a greater amount of information. Rather, expertise involves learning which aspects of a situation are meaningful for action and how different cues should be interpreted in relation to one another. In this sense, expert perception is not equivalent to passive observation of material properties; it is an active process of becoming selectively responsive to those differences that matter for accomplishing a particular task. Research on task complexity and element interactivity similarly suggests that the difficulty of skilled activity depends not only on the number of elements involved but also on the degree to which these elements must be processed in relation to each other (10). Thus, expert judgment cannot be reduced to the accumulation of isolated sensory inputs, because the significance of each cue emerges from its relationship with other cues and with the ongoing situation.

Ecological approaches to skilled action provide a useful theoretical foundation for understanding this process. Rather than treating perception as the internal reconstruction of objective properties, ecological theories emphasize that skilled agents become attuned to affordances, namely, possibilities for action that emerge from the relationship between environmental conditions and the abilities of the practitioner (4,11). From this perspective, affordances are not simply properties contained within objects; they become meaningful through the interaction

between what the environment offers and what the practitioner is capable of doing. Skilled intentionality therefore involves selective responsiveness to a field of relevant affordances within concrete situations rather than the independent evaluation of separate environmental features (4,5).

This perspective provides a useful way of interpreting how skilled judgments can be made without relying exclusively on explicit measurement. In the practices examined here, judgments concerning clay moisture, resistance, thickness, elasticity, and form appeared to be made relationally rather than as wholly independent evaluations. Instead, their practical significance emerges from their dynamic relationships and from the specific operation being performed. The same degree of resistance, for example, may indicate an appropriate material state during one stage of shaping but signal a potential problem during another stage requiring different manipulation. From this perspective, skilled perception can be understood as involving not only sensitivity to the physical condition of the clay, but also sensitivity to what that condition affords for subsequent action.

Accordingly, this study uses the concept of perceptual attunement to describe the learned capacity through which practitioners become selectively responsive to action-relevant material differences. Perceptual attunement does not refer simply to enhanced sensory sensitivity; rather, it involves the gradual calibration of attention,

discrimination, and interpretation through repeated engagement with materials and practices. Through such processes, practitioners develop what is termed "situated judgment," which is the ability to determine what a particular situation requires and how action should be adjusted accordingly. Perceptual attunement therefore constitutes the perceptual foundation through which tacit knowing becomes enacted in skilled practice.

3.3 Perception–action coupling

Tacit knowing is not only a matter of perceiving relevant differences; it also depends on the continuous interaction between perception and action. Skilled practice unfolds through iterative cycles in which practitioners act upon materials, perceive the consequences of those actions, and modify subsequent actions accordingly. Therefore, action should not be understood as a simple execution of prior judgment, but as a process through which new information about the material situation is generated.

This understanding is consistent with Sennett's (12) account of craftsmanship as a dialogue between crafter and material. In skilled crafting, materials are not passive objects upon which predetermined intentions are imposed. Because materials continuously transform through manipulation, drying, pressure, and environmental conditions, skilled practice requires sensitivity not only to material properties but also to their temporal development. Resistance, variation, and

unexpected responses from materials actively participate in shaping the practitioner's decisions. Similarly, Ingold (13) argues that crafting is a process of correspondence between practitioners and materials, in which knowledge emerges through ongoing engagement rather than through the application of a fixed mental plan. From this perspective, craftsmanship involves learning how to follow and respond to the evolving possibilities revealed through material interaction.

The perception–action relationship is particularly important in tactile craftsmanship because perception itself is often generated through movement. Research on haptic perception emphasizes that touch is not merely a passive reception of sensory signals but is closely connected with exploratory action and bodily movement (8). Through pressing, rotating, adjusting, and refining, artisans actively produce sensory information that allows them to evaluate material conditions. Consequently, skilled perception and skilled action develop together: actions reveal new properties of the material, while these perceptions guide subsequent adjustments.

This cyclical relationship also explains why tacit knowledge is difficult to preserve through documentation alone. Written descriptions or visual records can capture procedures, material characteristics, and observable outcomes, but they cannot fully reproduce the ongoing processes through which practitioners learn to

interpret changing situations. As Miton and DeDeo (14) argue, complex skills are often transmitted through forms of tacit teaching in which learners gradually acquire the ability to navigate interacting constraints rather than merely imitate observable actions. Apprenticeship therefore functions not only as a means of transferring technical information but also as a process through which practitioners develop the perceptual and adaptive capacities required for skilled engagement.

Taken together, perception–action coupling provides the dynamic mechanism linking tacit knowing with material practice. Skilled artisans do not first perceive a fixed reality and then respond to it; rather, they participate in a continuous process in which perception, judgment, action, and material feedback recursively shape each other.

3.4 From present state to material history

Situated judgment is often described in terms of responsiveness to the conditions currently encountered in action. Yet responsiveness to the present does not necessarily imply that the present condition is sufficient to explain the judgment. A material may carry consequences of earlier handling, deformation, drying, or rest that are not fully specified by a limited description of its immediately observable properties. Studies of thixotropic clay, for example, show that remoulding, aging, rest time, and shear history can alter subsequent mechanical or rheological behavior through

changes in material structure (6,7). These findings cannot be transferred directly to Zisha craftsmanship, but they provide a material-scientific basis for asking whether prior history might sometimes remain relevant to present craft judgment.

This distinction can be expressed as one between state-dependent and potentially history-dependent judgment. In a strictly state-dependent account, an adequately specified present state would contain all information relevant to the next appropriate action; the path by which that state was reached would add nothing further. A history-dependent account allows a different possibility: two materials that appear similar according to selected present-state variables may nevertheless call for different responses because their preceding histories continue to influence their action-relevant properties. In formal terms, this possibility is compatible with a non-Markovian interpretation of skilled material judgment, although the present study does not establish that such judgment in Zisha craftsmanship is in fact non-Markovian.

For the present analysis, history dependence is therefore treated as a hypothesis about skilled sensitivity rather than as an additional dimension of tacit knowledge. The four dimensions identified in this paper, namely tactile judgment, perceptual-aesthetic evaluation, coordinated bodily action, and temporal sensitivity, remain the principal analytic framework. The proposed extension concerns how information relevant to

these dimensions may be temporally organized. An experienced artisan may respond to the material not only as a configuration of properties perceived *now*, but as a condition understood in relation to *preceding* interactions. Such history-sensitive judgment would make the material's preceding trajectory part of the situated context within which perceptual cues acquire practical significance.

3.5 Analytical framework of this study

Based on the preceding discussion, this study conceptualizes tacit knowing as a dynamic process rather than as a static body of hidden knowledge. Skilled craftsmanship emerges through the ongoing recursive relationship among perceptual attunement, situated judgment, adaptive action, and material feedback. Within this recursive process, situated judgment may also be sensitive to the history through which the material's present condition has emerged. Material history is therefore not treated as a separate fifth dimension of tacit knowing, but as a potentially relevant temporal context within which present perceptual cues are interpreted and acted upon. Perceptual attunement enables practitioners to identify action-relevant material differences within complex situations; situated judgment allows them to determine appropriate responses; adaptive action transforms both the material state and the practitioner's subsequent perception. Existing scholarship suggests that repeated participation can progressively cultivate such embodied capabilities. The present analysis

examines why documentation alone may not reproduce the situated capacities involved in their enactment.

The following analysis examines tactile sensitivity, aesthetic judgment, bodily coordination, and temporal sensitivity as four interconnected manifestations of tacit knowing rather than as separate categories of tacit knowledge. Temporal sensitivity is understood here not simply as awareness of elapsed time, but as the situated capacity to judge when a material condition has become appropriate for action as it develops through an unfolding process of crafting. Although analytically distinguishable, these dimensions are enacted simultaneously during skilled practice and together support the continuous coordination of perception, judgment, and action through ongoing engagement with materials.

4. The material specificity of Zisha clay

To understand why tacit knowledge is central to Zisha teapot crafting, it is necessary to consider the material specificity of Zisha clay. Zisha clay is not a passive material that simply yields to the crafter's intention. It is a dynamic material that is affected by air and moisture, and it changes as it is pressed and shaped. Archaeometric research, using rigorous scientific laboratory methods—encompassing chemistry, physics, and geology—to analyze the physical and chemical structure of ancient artifacts, supports this emphasis on material specificity. Wu et al. (15) analyzed Yixing Zisha pottery from the late

Ming to late Qing periods and discovered that its chemical and phase composition, microstructure, and porosity are closely linked to its raw materials, production process, and functional performance. The same movements may produce different results depending on whether the clay is slightly wet, beginning to dry, or already too firm. This variability makes specific mechanical instruction on how to work the clay insufficient for the artisan's success.

The material also has a close relationship between form and function. A Zisha teapot must not only appear balanced; it must survive firing without cracking, maintain structural stability, hold heat properly, and pour smoothly. The importance of these functional qualities is also supported by materials research on Dicaoqing-Zisha. Yang et al. (16) found that Zisha differs from ordinary pottery and porcelain in crystal-phase composition and pore structure, which explains why the artisan's judgments about material condition, thickness and firing matter to both function and durability. A wall that is too thick may affect proportion and use, while a wall that is too thin becomes too fragile. The position of the spout and handle affects both visual harmony and balance. Therefore, the crafter's decisions are never purely aesthetic or purely technical.

This material variability makes Zisha craftsmanship particularly useful for examining situated tacit knowing. The problem confronting the artisan is not simply that material conditions

change, but that the practical relevance of each material cue changes with the developing object and the action being attempted. Skilled crafting therefore requires continuous perceptual attunement to the evolving material situation: small differences in resistance, moisture, surface condition, and form must be recognized in terms of what they permit, require, or constrain the crafter to do next (4,5).

5. The crafting process of Yixing Zisha teapots

The crafting of a Yixing Zisha teapot involves a sequence of operations that combine technical procedure and intuitive judgment. The process includes flattening clay slabs, shaping the body, adjusting the wall thickness, forming and attaching the spout and handle, fitting the lid, refining the surface, and preparing the object for firing.

Unlike wheel-thrown ceramics, many Zisha teapots are shaped through slab-building, paddling, pressing, and trimming. Gao et al. (17) trace chronological changes in Zisha clay recipes and argue that potters' choices were shaped by geological sources, clay processing, texture, color, and changing aesthetic preferences. The body is gradually formed rather than produced through a single mechanical motion. At each stage, the maker must judge whether the clay is firm enough to hold its shape but still soft enough to be shaped or joined. The process therefore requires constant adjustment rather than the simple repetition of fixed steps.

The components of the teapot must also work as a coherent system. The body, spout, handle, and lid are not independent parts. Their proportions and positions affect visual balance, pouring function, grip, and structural stability. This interdependence is important theoretically. Although the crafting process unfolds through a recognizable sequence of operations, the judgment required within any particular stage is not necessarily sequential. The artisan may need to respond concurrently to resistance, geometry, moisture, balance, and intended function as aspects of a single developing situation. The distinction between the temporality of the material process and the relational structure of expert judgment becomes particularly important in the discussion of codification below.

6. Four interrelated dimensions of tacit knowing in Zisha crafting

6.1 Tactile sensitivity

The most immediate form of tacit knowledge in Zisha crafting appears in tactile judgment. One example is the control of wall thickness. Although the desired wall may be described with words such as “even,” “moderate,” or “balanced,” these terms do not tell the maker exactly how much pressure to apply at a particular moment. The artisan must feel the resistance of the clay. Thickness is judged not only by sight, but by the relation between pressure and material response.

During observation, one experienced craftsman

explained that wall thickness is not first known by the eyes. When the hand presses the clay, it feels whether the resistance is even. If the resistance feels right, the thickness is likely to be appropriate. This explanation suggests that tactile judgment is not simply an imprecise substitute for measurement. Numerical measurement could in principle describe particular properties of the clay, but successful action requires the artisan to determine what those properties mean in relation to the developing object and the current task. Resistance, for example, is experienced while pressure is being applied and is interpreted in relation to moisture, thickness, flexibility, and the intended effect of the movement. Tactile judgment therefore reflects perceptual attunement to relation between action and material response, rather than the detection of a single stable variable. In ecological terms, the artisan becomes selectively responsive to material conditions in terms of the possibilities for action they afford (4,5). Tactile judgment therefore provides the perceptual foundation upon which situated judgment and adaptive action become possible during material engagement.

6.2 Aesthetic attunement

Tacit knowing also operates through perceptual and aesthetic evaluation. A Zisha teapot must achieve harmony among the body, spout, handle, and lid. Although artisans may refer to general rules of proportion, these rules do not determine the final form. A teapot can satisfy geometric

proportions and still appear visually unbalanced. Conversely, a small adjustment that is difficult to describe numerically may make the whole object appear more aesthetically whole.

This kind of judgment is more than a matter of subjective preference. It reflects a trained perceptual attunement developed through repeated exposure to forms, corrections, comparisons, and prior examples. Experienced artisans learn to notice whether a curve appears too 'heavy', whether a spout disrupts the balance of the body, or whether a lid appears integrated into the whole form. Such judgments depend on relationships among parts rather than on any isolated geometric property.

Perceptual-aesthetic evaluation can therefore be understood as another form of attunement. General principles of proportion may guide attention, but they do not by themselves determine whether a particular object "works" aesthetically. The skilled craftsman has learned to perceive small but action-relevant formal differences within the configuration of the whole object. What is learned is consequently not only a set of aesthetic criteria, but an increasingly discriminating way of seeing. Perceptual-aesthetic evaluation therefore illustrates how perceptual attunement enables practitioners to recognize action-relevant formal relationships before they are translated into skilled action.

6.3 Bodily coordination

Tacit knowing is also expressed through bodily

coordination during the continuous interaction between the artisan and the material. The movements involved in Zisha crafting cannot be reduced to a sequence of fixed techniques to be mechanically reproduced. Instead, each action must be continually adjusted according to the changing condition of the clay. The pressure applied by the fingers, the angle of the wrist, the speed of rotation, and the coordination of both hands vary throughout the crafting process as the material gradually changes in moisture, thickness, and form.

During field observation, experienced artisans repeatedly emphasized that successful shaping depends on “following the clay” rather than imposing predetermined movements upon it. Although novice apprentices can imitate visible hand movements, they often fail to reproduce the same results because they are unable to modify those movements in response to subtle material changes. Skilled coordination therefore depends not simply on motor repetition, but on the continuous adjustment of bodily movement in relation to evolving material conditions.

This understanding is consistent with Sennett’s (12) description of craftsmanship as a dialogue between the craftsman and the material. Likewise, Ingold (13) argues that crafting is not the execution of a preconceived plan but an ongoing process of correspondence in which practitioners continuously respond to the possibilities emerging through material engagement. Bodily coordination can therefore

be understood as an adaptive process rather than a stable motor routine. Skilled action does not merely implement prior judgment; it continually generates new information about the material, allowing perception and judgment to be recalibrated during the unfolding process of crafting.

Accordingly, bodily coordination illustrates how adaptive action becomes an integral component of tacit knowing. Through repeated practice, artisans gradually develop the ability not simply to perform particular movements, but to coordinate perception and action as an integrated response to continuously changing material situations.

6.4 Temporal awareness

The final manifestation of tacit knowing concerns temporal sensitivity: the capacity to recognize when a changing material condition has become appropriate for a particular action. In the Zisha practices observed here, timing was not organized solely by predetermined intervals. Clay continued to change during shaping, drying, and finishing, and the transition from one operation to another depended on the artisan’s judgment of whether the material had become suitable for what needed to be done next. Temporal sensitivity therefore concerns not simply knowing how long to wait, but recognizing when action has become appropriate within an evolving material situation.

This distinction was reflected in artisans’

descriptions of “waiting until the clay is ready.” Readiness was not treated as a single measurable property or as the result of a fixed duration. Artisans attended to changes in moisture, firmness, surface texture, and resistance while also considering the requirements of the subsequent operation. The appropriate moment for attaching a component, refining a surface, or proceeding to another stage therefore emerged from a relational judgment: a material condition became significant as “ready” in relation to a particular intended action. Knowing when to act, in this sense, involved perceptual attunement to a changing configuration of cues and situated judgment about what that configuration currently afforded.

The novice experience provides a useful contrast. During participant observation, verbal instructions such as “waiting until the clay is ready” did not by themselves enable successful action. The difficulty was not simply remembering that a period of waiting was required, but recognizing what counted as readiness in the material itself. This suggests that temporal sensitivity is learned through the calibration of perception rather than through the memorization of standardized intervals. With repeated engagement, practitioners become better able to distinguish conditions that call for continued waiting, immediate intervention, or transition to the next operation.

Temporal sensitivity may also extend beyond responsiveness to the material's immediately

perceived condition. Because each intervention alters the conditions inherited by subsequent stages, the practical meaning of a present cue may sometimes depend partly on how that condition has developed. A particular degree of firmness or resistance, for example, may be interpreted in relation to preceding handling, drying, or adjustment rather than as an isolated present-state value. In this sense, skilled timing can be understood as temporally situated: practitioners respond to the material as part of an unfolding process rather than as a sequence of disconnected states.

The present observations do not establish that prior material history contributes information independently of a sufficiently detailed characterization of the material's current internal state. They nevertheless support a more focused hypothesis: some skilled judgments about when to act may be history-sensitive, insofar as artisans interpret present material conditions in relation to preceding interactions and transformations. Temporal sensitivity is therefore understood here as the learned capacity to identify action-relevant transition points within an evolving material process, potentially integrating both present perceptual cues and the material trajectory through which those cues have emerged.

7. Apprenticeship as perceptual and attentional calibration

The dissemination of tacit knowing in Zisha crafting is cultivated primarily through apprenticeship. Apprenticeship extends far

beyond the simple imitation of visible techniques. A beginner may watch the master's hand movements carefully and still fail to reproduce the same result. What the beginner lacks is not only technical information, but also the ability to recognize what is relevant for action: the resistance of the clay, the degree of moisture, the balance of the form, the pressure of the hand, and the timing of each action. In this sense, apprenticeship involves learning how to perceive and interpret material situations rather than simply acquiring procedural knowledge. This understanding is consistent with situated learning perspectives, which emphasize that learning occurs through participation in meaningful practices rather than through the passive acquisition of abstract information (18).

Recent research on Chinese traditional handicraft inheritance supports this view. Song et al. (19), based on interviews with 37 participants and 21 master-apprentice groups in four Chinese handicraft inheritance institutions, show that craft transmission depends not only on technical demonstration, but also on interaction, feedback, and the formation of inherited behavior. Such findings highlight that apprenticeship involves the cultivation of practical sensitivity that cannot be fully separated from the social and material context in which skills are performed.

For this reason, apprenticeship can be understood as a process of perceptual and attentional calibration. The master does not merely instruct

the apprentice what to do; he guides the apprentice toward what to feel, where to look, and when to adjust. During field observation, one craftsman advised the researcher not only to watch his hands but also to attend to how the clay reacted to the movement. Such guidance directs attention away from reproducing a visible action at a predetermined moment and toward recognizing changes in the material that make adjustment appropriate. Learning when to act therefore develops together with learning what material responses are significant for the operation being performed.

This calibration is also temporal. Repeated participation exposes apprentices to material conditions as they develop through handling, adjustment, waiting, and further intervention. Over time, learners may become sensitive not only to whether the clay appears ready at a particular moment, but also to how its present condition relates to preceding interactions. Apprenticeship can therefore cultivate temporally situated judgment by helping learners connect present perceptual cues with both the demands of the next action and the unfolding process through which the material condition has emerged.

Repetition is central to this process, but its purpose is not mechanical uniformity. Through repeated practice, apprentices learn to make finer distinctions. They begin to distinguish clay that is too wet from clay that has become appropriate for the next operation, a wall that is

merely thin from one that is evenly balanced, and a lid that fits from one that belongs naturally to the whole teapot. Mistakes are not simply failures; they function as feedback through which perception becomes more precise and action becomes better calibrated. As Sennett (2008) argues, craftsmanship develops through sustained engagement in which repetition generates increasing sensitivity rather than simple reproduction.

This form of learning challenges a narrow view of education as the transfer of information. In Zisha apprenticeship, knowledge is not handed over as a complete verbal explanation. It is gradually cultivated through guided practice, correction, observation, and embodied participation. The apprentice learns not only how to make a teapot, but how to perceive and respond to material situations in a skilled way. These observations, together with existing scholarship, suggest that apprenticeship provides an important context for the acquisition and transmission of tacit knowing: it develops the capacity to perceive action-relevant differences, interpret changing conditions, and adapt skilled action within an unfolding craft process (14).

8. Discussion

8.1 Contribution to tacit knowledge studies

The contribution of this analysis lies in examining how experience in Zisha crafting can be interpreted as an interaction among touch, sight, bodily coordination, material change, and

guided apprenticeship. The case of Zisha teapot crafting suggests that tacit knowledge should not be understood as a vague or mysterious form of knowledge. It can be analyzed through specific dimensions: tactile judgment, perceptual-aesthetic evaluation, coordinated bodily action, and temporal sensitivity. These dimensions are distinguishable, but in practice they work in unison. The present analysis further suggests that the temporal organization of such judgment may deserve closer attention. Skilled responsiveness need not concern only relations among cues available at a particular moment; in some cases, the practical significance of those cues may also depend on the material's preceding history. History dependence is therefore proposed here not as a fifth dimension of tacit knowledge, but as a hypothesis about how the four dimensions may operate across time. What an artisan feels, sees, or judges in the present may acquire its action-relevant meaning partly through earlier processes of drying, handling, deformation, correction, and rest. The present case study cannot determine whether such history sensitivity would persist after a sufficiently rich characterization of the material's current internal state, or whether it reflects properties of that state that remain unobserved in the present analysis. Its contribution is therefore to identify the distinction between state-dependent and potentially history-dependent judgment as a theoretically and empirically testable problem for future research.

This case is consistent with and helps illustrate

the multidimensional and relational character of tacit knowing. Tacit knowledge is not simply “knowledge in the hand” or “knowledge that cannot be spoken.” It is a practical capacity that emerges through the interaction of body, material, tool, time, and social learning.

8.2 Why representation cannot fully reproduce tacit knowing

The foregoing analysis suggests a more specific explanation for why documentation can preserve substantial information about Zisha craftsmanship without thereby reproducing the skilled capacity involved in its performance. The limitation does not arise simply because craft practice is complex. Complex processes can often be represented through measurements, diagrams, computational models, and conditional procedures. Nor does tacitness imply that relevant material variables are inherently immeasurable. Moisture, temperature, dimensions, pressure, resistance, and other material properties can in principle be measured with increasing precision. The more important distinction is therefore not between what can and cannot be represented, but between representing information about a situation and acquiring the situated capacity to recognize what that information means for action.

The deeper difficulty concerns how represented information becomes action-relevant. Documentation can identify variables, record sequences, preserve exemplary forms, and specify relationships among material conditions.

Yet skilled judgment requires more than access to those representations. Practitioners must recognize which differences matter in the situation presently unfolding, how strongly they matter, and what they imply for the action being attempted. Resistance, for example, does not have a fixed practical meaning in isolation; its significance varies with moisture, thickness, geometry, the developing form, the intended action, and potentially the material's preceding history. Skilled perception therefore involves not merely detecting represented features, but discriminating their situated significance within an integrated field of possibilities for action. Ecological approaches characterize this kind of expertise in terms of selective responsiveness to relevant affordances within concrete situations (4,5).

This point also refines the distinction between sequential material change and concurrent expert judgment. Zisha production necessarily unfolds through time: one operation precedes another, moisture changes, and each intervention modifies the conditions inherited by the next stage. Yet the judgment governing movement through this sequence need not consist of a serial checklist of independent variables. At a particular moment, moisture, resistance, thickness, geometry, intended action, and other cues may be encountered as mutually conditioning aspects of an integrated situation. In this sense, the workflow is sequential while the perceptual organization of judgment may be concurrent and relational. At the same time,

concurrent judgment should not be assumed to be history-free: as argued above, the practical significance of a present configuration may sometimes be interpreted in relation to the material trajectory through which it has emerged.

This argument should not be taken to imply that symbolic or computational systems are incapable of representing complex relations or material histories. Contemporary sensing and modeling systems can record multivariate states, temporal sequences, prior interventions, and increasingly detailed material trajectories. A sufficiently rich representation might therefore capture far more of the information relevant to craft judgment than conventional written instructions can. The claim advanced here is narrower: representation of such information is not equivalent to the learned capacity to discriminate its action-relevant significance in situated performance. A model may specify that several variables and prior states matter; this does not by itself confer on a learner the perceptual calibration through which those relations become salient, differentiated, and actionable in ongoing material engagement (3,9).

A second limitation of representation concerns the generative role of action itself. Skilled action does not merely implement a judgment formed from information already available; it also helps generate the information on which subsequent judgment depends. An artisan may press the clay, feel its response, alter the pressure, pause, reposition a component, and reassess. Such

interventions both transform the material and reveal aspects of its condition. Consequently, the relevant context is not always fully given before action begins. It is partly produced through the evolving perception–action relation itself. Skilled performance therefore depends on maintaining sensitivity within a closed loop of perception, action, material response, and renewed judgment rather than simply consulting a pre-existing representation of a fixed situation. This interpretation is consistent with interactionist accounts of skilled performance that emphasize ongoing real-time adaptation across brain, body, and environment rather than the execution of fully specified instructions (20).

The possibility of history-sensitive judgment adds a further qualification. If the action-relevant meaning of a present condition depends partly on how that condition was produced, a representation restricted to selected present-state variables may omit information that practitioners use in judgment. Expanding the representation to include prior states and interventions may reduce this limitation, but it does not remove the distinction between encoding a material trajectory and learning how to interpret that trajectory in relation to present affordances. History dependence therefore does not demonstrate that craft knowledge is intrinsically unrepresentable; rather, it clarifies why increasingly complete representation and skilled situated responsiveness should be treated as analytically distinct achievements.

Documentation consequently remains indispensable but should not be treated as functionally equivalent to skilled participation. Texts, videos, sensors, and digital models can preserve procedures, variables, relations, and potentially detailed material histories. They can direct attention, support comparison, and make otherwise subtle changes more explicit. What representation alone does not guarantee is the acquisition of the perceptual calibration, embodied responsiveness, and situated judgment through which represented information becomes actionable in an evolving material encounter. The preservation problem is therefore not whether tacit knowledge can simply be “captured” or “not captured,” but how representations can be integrated with forms of participation through which the capacities required to enact skilled knowing are cultivated.

8.3 Implications for intangible cultural heritage

This analysis also has implications for understanding intangible cultural heritage. Traditional craftsmanship is often valued for its visible products, such as completed teapots, distinctive forms, or regional styles. However, the heritage of Zisha crafting does not reside only in finished objects. It also resides in embodied judgments. This point is consistent with broader ICH scholarship, which emphasizes that intangible heritage is not simply a collection of preserved objects or texts, but a living system of practices, skills, cultural spaces, and intergenerational legacy. Recent research on traditional handicrafts and sustainable intangible

cultural heritage also emphasizes that preservation depends not only on recording finished products, but on maintaining the practices, makers, transmission environments, and social conditions that allow craft knowledge to continue (21). The ability to feel clay readiness, judge proportion, coordinate components, and teach apprentices is, itself, part of the heritage.

Recognizing tacit knowing as a cultivated capability changes how preservation should be conceptualized. Documentation remains essential for recording objects, procedures, terminology, historical knowledge, and exemplary practices. However, the preservation of representation is not identical to the preservation of the capability to enact a practice. For craft traditions such as Zisha crafting, safeguarding may therefore also benefit from maintaining conditions in which perceptual attunement, situated judgment, and adaptive action can continue to develop through repeated material engagement and interaction with more experienced practitioners. In this sense, heritage preservation involves not only preserving what practitioners know, but sustaining the environments through which practitioners can continue to learn how to know.

8.4 Implications for education and digital heritage preservation

The case of Zisha crafting also invites reflection on education. In many educational settings, knowledge is treated as information that can be written, memorized, and transferred. Zisha

apprenticeship shows another model of learning: knowledge develops through attention, practice, correction, and embodied response. This does not mean that verbal explanation is unimportant. Rather, it suggests that explanations must be connected to guided action.

The same insight is relevant to digital heritage projects. Digital modeling, video recording, sensor-based documentation, and archival documentation can preserve increasingly rich representations of craft processes, including aspects of movement, form, material condition, and procedural sequence. Such technologies should therefore not be dismissed as incapable of representing tacitly relevant information. The theoretical issue is instead whether representation alone can cultivate the perceptual and judgmental capacities through which such information becomes meaningful in action. This distinction remains even where digital systems capture increasingly rich temporal information: recording how a material state developed is not by itself equivalent to learning how that history changes what the present situation affords. Li (22) argues that digital communication of handicraft ICH is shaped by practitioner awareness, cultural communication initiative, technological adaptability, audience acceptance, and uncontrollable contextual factors. A video may direct learners toward features of hand movement, and sensor data may make otherwise subtle material changes more explicit; however, learners must still develop the ability to connect such representations with the situated demands

of actual material engagement. Digital preservation may therefore be most effective when used to support, extend, and enrich embodied apprenticeship rather than when treated as a substitute for the perceptual calibration developed through practice.

8.5 Limitations and future research

The proposed history sensitivity of skilled judgment should be treated as a theoretical hypothesis rather than as an empirical finding established by the present study. The current case shows that artisans encounter material conditions that develop through preceding handling, drying, waiting, and adjustment, and that they interpret those conditions within an unfolding process of crafting. It does not, however, determine whether prior history contributes information beyond what could be captured by a sufficiently rich description of the material's present internal state. This distinction is important because apparently history-dependent behavior may sometimes be represented through additional internal or state variables that summarize the consequences of preceding processes.

Future research could examine this distinction through controlled comparisons of materials that arrive at similar measured present conditions through different trajectories. For example, clay samples could be prepared through different sequences of drying, resting, compression, or manipulation and then matched as closely as possible on observable present-state variables such as moisture, temperature, geometry, and

selected mechanical properties. Experienced artisans could then be asked to judge readiness or select an appropriate subsequent action. If prior trajectory improves the prediction of expert judgment beyond the measured present state, this would provide evidence for history sensitivity relative to the variables included in that state description. It would not, by itself, demonstrate that the dependence on history is irreducible.

A further step would therefore be to enrich the characterization of the present material state. Material-science approaches to history-dependent systems often introduce internal variables that summarize structural consequences of prior deformation or processing, and recent computational work has shown that such variables can sometimes be inferred from history-dependent material responses (23). Combining craft judgment with rheological, mechanical, or microstructural measurements could help determine whether an apparent effect of prior trajectory is mediated by latent properties of the current material state. If the contribution of trajectory diminishes as these variables are incorporated, the phenomenon would be better interpreted as state dependence under an initially incomplete state description. If trajectory remains informative, it would motivate further investigation of what additional material or perceptual processes carry that historical information.

Future studies should also distinguish material history from the history of the practitioner's own

perception and action. The present paper focuses primarily on the possibility that previous material transformations influence the significance of current cues, but skilled judgment may also be affected by preceding perceptual experience, exploratory actions, and expectations. Experimental designs that independently manipulate material trajectory and practitioners' recent interaction history would therefore help clarify where history sensitivity resides and how it becomes integrated within situated judgment. Such research would move the present theoretical proposal toward a more precise empirical account of how temporal continuity contributes to tacit knowing.

8.6 Perspectives

The present framework suggests that craftsmanship is especially, although not exclusively, valuable when heterogeneous materials or process-sensitive transformations leave consequential variation that cannot be reliably captured by standardized procedures and current-state measurements. This often applies to natural materials such as clay, wood, and leather, but the operative distinction is not "natural" versus "manufactured." It is the degree of compositional variability, history dependence, and residual uncertainty remaining during production. Natural materials can be incorporated into assembly-line manufacture when their initial composition is screened or homogenized and critical processing conditions are controlled. As this standardization becomes more complete, continuous artisan judgment

may become less technically necessary. Craftsmanship may nevertheless retain cultural and economic value through authorship, customization, aesthetic distinction, provenance, rarity, and demonstrable mastery, even when standardized production can achieve equivalent functionality.

Similar relationships occur beyond Zisha crafting. In artisanal wine, grape properties reflect interacting effects of soil, climate, cultivar, vintage, and geographically structured microbial communities, while fermentation, oxygen exposure, temperature, aging, and blending add further process dependence. Traditional blades provide a materials-science example: Japanese *tamahagane* is compositionally and microstructurally heterogeneous, whereas wootz-derived Damascus blades depend on process-sensitive carbide distributions produced through solidification and thermal–mechanical history. In Kolhapuri chappal crafting, artisans must accommodate local differences in hide thickness, fibre orientation, stiffness, moisture response, and surface condition while cutting, stretching, braiding, stitching, and fitting leather whose collagen structure has already been altered by tanning. Comparable interactions occur in violin crafting, glassblowing, cheesemaking, sourdough production, lacquerware, hand papermaking, natural dyeing, timber joinery, tea processing, and ceramic firing. These practices are not scientifically inexplicable; rather, their relevant composition–process–structure

relationships may not yet be measurable or controllable with sufficient completeness and economy to determine every production decision prospectively.

The future of craftsmanship may therefore lie neither in resisting industrialization nor in mechanically reproducing artisanal movements, but in identifying where material variability, processing history, exploratory interaction, and aesthetic discretion remain consequential. Hybrid systems could assign repeatable operations to standardized technologies while retaining artisans—or adaptive sensing systems—at stages where present-state specifications are insufficient. Future research should consequently compare production systems according to the material histories, judgments, and forms of value that they preserve or eliminate, rather than assuming an inherent opposition between craft and industrial production.

9. Conclusion

This paper examined Yixing Zisha teapot crafting as a case study of tacit knowing in traditional craftsmanship. Through participant observation and theoretical analysis, it argues that Zisha crafting depends on more than explicit instruction or technical procedure. Its knowledge emerges through tactile judgment, perceptual-aesthetic evaluation, coordinated bodily action, temporal sensitivity, and apprenticeship-based attention training. Rather than treating these dimensions as separate repositories of tacit

knowledge, the study interpreted them as interdependent manifestations of a broader process involving perceptual attunement, situated judgment, and adaptive action. In particular, temporal sensitivity was interpreted not simply as knowing how long to wait, but as the situated capacity to recognize when changing material conditions make a particular action appropriate; the analysis further proposes that such judgments may sometimes be sensitive to the material history through which those conditions have emerged. Whether this apparent history sensitivity reflects information carried by prior trajectory itself or by as-yet-unmeasured features of the current material state remains an open empirical question.

This process-oriented interpretation provides a more precise account of why skilled craft practice remains difficult to preserve through documentation alone. The relevant problem is not simply that craft knowledge is too complex to describe, nor that its material variables are inherently impossible to measure. Rather, successful performance depends on a learned capacity to recognize the action-relevant significance of relations among present material conditions, intended actions, prior interactions, and ongoing material feedback. Representation of these elements may therefore support transmission without being equivalent to the cultivated ability to respond to them in an unfolding situation.

Apprenticeship is central to this account because

it provides a setting in which attention and perception can be progressively calibrated. Through demonstration, correction, repetition, and material feedback, learners become increasingly capable of noticing relevant differences and acting on them appropriately. These findings suggest that the preservation of traditional craft may need to consider not only objects, procedures, and records, but also the social and material environments in which skilled ways of perceiving, judging, and acting can continue to develop.

In this sense, “learning through the hand” does not mean that knowledge is located literally in the hand. It means that, in skilled craftsmanship, the hand does not merely execute what the mind already knows; through sustained engagement with the material, it helps discover what must be done next.

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Ethics statement

This exploratory case study involved non-sensitive personal information was collected.

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