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From Thread to Number: Weaving as scaffold for mathematical thinking

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Abstract

Mathematical cognition is often studied through formal systems or experimental tasks, leaving open how abstract numerical concepts emerge from everyday practices. This paper reviews ethnographic and ethnomathematical studies of weaving crafts, arguing that these practices minimally and systematically recruit a set of cognitive capacities that are central to quantification: grouping, ordering, pairing, memory, exhaustion detection, and cardinality. Across cultures and technologies, weaving stabilizes these capacities through material constraints, procedural regularity, and visual structure, affording the emergence of geometric and numerical knowledge. Therefore, weaving is put forward as a model system for studying the embodied and culturally scaffolded origins of mathematical abstraction, with implications for theories of numerical cognition and material engagement.

Keywords: Embodied cognition; weaving; numerical cognition; cultural affordances; cross-cultural mathematics

1. Why crafts matter for mathematical cognition

Mathematical cognition is often investigated through formal symbolic systems (Mussolin et al., 2012), laboratory-based numerical tasks (Dehaene, 2009), or the historical development of explicit number notation (d'Errico et al., 2018). While these approaches have yielded substantial insights into the properties of mature mathematical reasoning, they leave open a fundamental question: how abstract mathematical ideas emerge from everyday human activity (Lakoff & Núñez, 2000). In particular, there remains a gap between accounts of numerical cognition grounded in innate capacities or symbolic representations, and the rich body of evidence showing that mathematical concepts are deeply shaped by embodied action, material culture, and culturally transmitted practices (Bender & Beller, 2011).

Weaving and related fibre crafts provide a compelling, yet underexplored domain, for addressing this gap. Across cultures and historical periods, weaving involves the systematic interlacing of flexible materials through repeated, systematic actions. These practices are widespread, technologically diverse, and often transmitted without formal notation, relying instead on embodied skills, procedural knowledge, and material regularities (Bier, 2004; Tuck, 2009). As such, weaving offers a naturalistic context in which to examine how structured mathematical relations, such as order, proportion, symmetry, and number, can arise from practical engagement with material systems (Belcastro & Yackel, 2023).

From a cognitive perspective, weaving is notable because it recruits a constellation of basic cognitive capacities that are also central to quantification and mathematical reasoning (Ascher, 2017; Gerdes, 2003). These include grouping and partitioning elements, ordering actions in time, pairing and matching components, maintaining intermediate states in memory, detecting completion or exhaustion, and tracking quantities (Núñez, 2009). Crucially, these capacities are not exercised in isolation but are stabilized and coordinated through the material constraints of fibres, knots, grids, and looms. Mathematical descriptions of material culture often focus on symmetry (Washburn, 2024). However, symmetry, even if planned, is merely the outcome of different (often convergent) manual and cognitive operations undertaken during weaving, which make abstract spatial relations perceptually salient and manipulable, allowing geometric structure to be enacted rather than merely represented.

This aligns closely with the account of mathematics proposed by Lakoff and Núñez (2000), who have argued that mathematical concepts are grounded in embodied experience and the systematic projection of structure from sensorimotor domains. On this view, mathematics does not emerge at once as a purely symbolic system, but is built through culturally mediated practices that recruit and extend everyday cognitive operations. Weaving, we suggest, constitutes one such practice: a material and cultural niche in which embodied actions and spatial relations are repeatedly coordinated in ways that afford the abstraction of mathematical structure.

In this paper, we present an integrative review of ethnographic, ethnomathematical, and cognitive studies of weaving. Rather than cataloguing techniques or motifs, it synthesizes evidence for a small set of recurring cognitive capacities engaged in weaving practices across cultures. Six of these capacities (grouping, ordering, pairing, memory, exhaustion detection, and cardinality) are suggested as a possible scaffold for numerical cognition (Table 1). By treating weaving as a model system for the embodied and culturally scaffolded origins of mathematical ideas, this review aims to contribute to broader debates in cognitive science concerning the nature of abstraction, the role of material engagement, and the developmental pathways leading from action to number.

2. Weaving as a material-cognitive system

Fibre technologies encompass a broad class of practices in which plant- or animal-derived fibres are transformed into functional artefacts through operations such as knotting, twining, braiding, netting, basketry, and textile weaving. Despite their technical diversity, these practices share a

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common principle: the continuous interlacing of flexible linear elements to produce stable two- or three-dimensional structures (Adovasio, 2016). The resulting artefacts, ranging from nets and baskets to garments and loom-woven textiles, are among the most widespread and long-lived forms of human material culture, despite being archaeologically underrepresented due to the perishable nature of their materials (Soffer et al., 2000).

At a minimal level, weaving requires the repeated coordination of actions in space and time. Fibres must be grouped, oriented, tensioned, and interlaced according to culturally defined procedures, often without recourse to external measurement tools or written instructions (Gerdes, 2003). More complex fibre technologies, such as loom weaving, further require advance planning, the maintenance of intermediate states, and the anticipation of how local actions will scale to global form (Maynard & Greenfield, 2003). Importantly, these operations are not arbitrary: the physical properties of fibres, i.e., flexibility, resistance, length, and continuity, impose constraints that shape what configurations are possible, stable, or functional. As a result, weaving practices tend to converge on regular patterns, repeated sequences, and structured spatial relations (Fanfani et al., 2025).

These features make weaving a particularly suitable, yet underused, model system for the cognitive science of mathematics (Bier, 2004). It is a practice that externalizes cognitive operations into durable material form, integrates multiple cognitive domains such as motor control, spatial reasoning, memory, and quantity processing, within a single, ecologically valid activity, and exhibits a high temporal depth and degree of cross-cultural recurrence. Independent weaving traditions have, for thousands of years, repeatedly recruited similar operations and produced comparable structural regularities, suggesting that the practice reliably engages shared cognitive resources rather than culturally idiosyncratic conventions alone (Harlizius-Klück & McLean, 2021). At the same time, weaving is culturally embedded and often transmitted through apprenticeship, narrative, and ritual, making it an ideal case for examining how cognitive capacities are stabilized, elaborated, and transmitted through social learning (Maynard et al., 2015).

Finally, weaving spans a spectrum of technical complexity, from simple looped nets to highly formalized loom-based pattern systems. This spectrum allows comparison across levels of abstraction, illuminating potential pathways by which practical action gives rise to increasingly explicit numerical and geometric concepts.

For these reasons, weaving can be treated as a material-cognitive system that affords mathematical structure (Bier, 2004). In the sections that follow, we review evidence that weaving practices across cultures minimally engage a small set of cognitive capacities central to quantification. By focusing on these capacities rather than on specific techniques, we aim to clarify how mathematical ideas can emerge from embodied action and material constraint, prior to formal symbolization.

3. Key cognitive capacities recruited in weaving

This brief review draws on ethnographic, ethnomathematical, and anthropological studies of fibre crafts across diverse cultural contexts. We selected studies that explicitly describe production processes and infer cognitive operations involved in non-industrial weaving, basketry, netting, and loom-based textile production, focusing on recurring cognitive capacities reported across independent traditions. We found that this literature broadly converges on a small set of cognitive capacities that plausibly scaffold mathematical abstraction: grouping, ordering, pairing, memory, exhaustion detection, and cardinality. These are all fundamental to mathematical thinking (Núñez, 2009). For each capacity, we offer below a brief description, its application in weaving, and its relevance to mathematical thinking.

3.1 Grouping and unit formation

Grouping refers to the cognitive capacity to aggregate discrete elements into bounded sets that can be treated as single units. Grouping is foundational to quantification: by enabling the formation of units, it supports comparison across collections, and underlies operations such as partitioning and divisibility (Núñez, 2009). Rather than requiring symbolic number, grouping allows quantities to be stabilized through perceptual and action-based regularities, providing a bridge between continuous material engagement and discrete numerical structure.

Ethnographic accounts of weaving consistently report practices in which fibres are grouped into regular bundles that function as operative units during production. In loom weaving, for example, warp threads are commonly arranged into fixed sets, often determined by heddles or pattern requirements, which are treated as single entities when lifted, separated, or crossed by the weft. These warp sets are not counted individually at each step; instead, they are manipulated as grouped units whose internal structure is temporarily backgrounded (Gerdes, 2011).

Similar practices are reported in pattern weaving traditions across Southeast Asia (Chudasri et al., 2025; Daniel et al., 2025; De las Peñas et al., 2014; Dominikus et al., 2017; Kerfant, 2022), where motifs are constructed by repeating groups of threads or colour sequences that define the basic unit of the design. In basketry and net weaving, grouping is equally central. Basket makers frequently bundle reeds, grasses, or strips of bark to establish the thickness, rigidity, or spacing of the structure, adjusting the size of bundles to control the final form of the artefact (De las Peñas et al., 2014; Gerdes, 2003; Kerfant, 2022). In looped netting traditions, such as the bilum bags of Papua New Guinea, the mesh is constructed through the repetition of loop units, each defined by a fixed number of knots and crossings. These loop units function as discrete building blocks, allowing the weaver to scale the object while maintaining proportional regularity (Ingold, 2001; Kerfant, 2022).

Across these cases, grouping emerges as a practical solution to managing many elements simultaneously, reducing cognitive load while increasing structural predictability. By treating a bundle of threads or a repeated motif as a single operative unit, weavers implicitly establish equivalence relations among sets and enable partitioning of a whole into equal parts. This supports operations analogous to division and multiplication, even in the absence of explicit numerical symbols.

3.2 Ordering and sequential control

Ordering refers to the cognitive capacity to organize actions or elements into a stable sequence, such that relative position (what comes before, after, or between) is preserved across repetitions. Ordering is central to procedural control and forms the basis of ordinal structure, enabling agents to track progression through a series of steps without necessarily assigning explicit numerical values (Núñez, 2009). Sequential control allows complex activities to unfold over time by maintaining the correct order of operations, even when individual steps are repeated or nested within larger routines.

Weaving practices across cultures place strong demands on ordering and sequential control, as the production processes of fibre artefacts typically involve fixed sequences of actions that must be executed in the correct order to achieve a functional result. In looped netting traditions, such as the bilum weaving mentioned above, the construction of the mesh depends on repeating a precise sequence of knotting and looping actions. Deviating from this sequence, for instance by reversing a step or skipping a loop, disrupts the regularity of the net and compromises its structural integrity. The weaver therefore relies on maintaining an ordered procedural script that is iterated across rows, with each step indexed relative to previous ones (Ingold, 2001; Kerfant, 2022).

In basketry traditions worldwide, the construction of bases, walls, and rims follows ordered phases that must be completed in succession so as not to compromise the structural integrity of the basket (Adovasio, 2016). For example, the establishment of a basket base typically precedes the raising of the walls, which in turn precedes the finishing of the rim. Within each phase, the interlacing of elements follows a repeated over-under order that must be preserved as the weave progresses (Gerdes, 2011). This layered structure of sequencing (operations and suboperations) requires the weaver to maintain multiple levels of ordinal control, ensuring that local actions align with the global form of the object (Adam, 2010; Gerdes, 2011; Jørgensen et al., 2023).

In loom weaving, ordering is further formalized through pattern repetition. Motifs are generated by executing ordered sequences of thread crossings that recur at regular intervals along the warp. Weavers track their position within a sequence not by counting individual actions, but by recognizing where they are in the pattern cycle. This reliance on ordinal position, i.e., knowing “which step comes next”, allows complex designs to be produced without written notation, using procedural memory and perceptual cues to guide action (Daniel et al., 2025; Dominikus et al., 2017; Franquemont & Franquemont, 2004). These sequences may be recalled by mnemonic aids, such as songs or stories, as in the cases of classical antiquity (Fanfani et al., 2025; Tuck, 2009) and Persian carpet weaving (Rafiepour & Moradalizadeh, 2022; Tuck, 2006).

By organizing actions and elements into stable sequences, weaving practices instantiate relations of precedence and succession that are essential to mathematical reasoning about order. In this sense, ordering and sequential control in weaving exemplify how temporal structure in action can give rise to abstract ordinal relations, providing a pathway from procedural skill to formal mathematical concepts.

3.3 Pairing and correspondence

Pairing refers to the cognitive capacity to establish systematic one-to-one relations between elements, actions, or groups, such that items can be matched or aligned across positions or sets (Núñez, 2009). Pairing and correspondence underlie equivalence relations and play a central role in both numerical cognition and symmetry detection.

Weaving practices recurrently recruit pairing and correspondence through the production of symmetrical and mirrored structures (Figure 1). In loom weaving traditions, motifs are often constructed around a central axis, requiring the weaver to ensure that actions performed on one side of the warp are matched by corresponding actions on the other. This involves pairing threads, colours, or crossings such that each element on one side has an equivalent counterpart. Ethnographic studies of pattern weaving describe how weavers maintain symmetry by mirroring sequences of thread manipulations, relying on visual alignment and procedural memory rather than explicit measurement (Chudasri et al., 2025; Franquemont & Franquemont, 2004; Gilsdorf, 2009; Küchler, 2017; Maynard & Greenfield, 2003; Medina et al., 2024).

Correspondence is also central in basketry and mat weaving, where structural balance depends on maintaining paired relations among elements. For example, in plaited basketry, stakes are frequently arranged in opposing pairs or intersecting sets that must remain evenly distributed to preserve the shape and stability of the object. If one side receives more material or tighter tension than its counterpart, the resulting asymmetry becomes immediately perceptible. Weavers therefore engage in continuous monitoring of paired relations, adjusting actions to maintain correspondence across the structure (De las Peñas et al., 2014; Gerdes, 2003; Pradhan, 2020).

Establishing that two sets, positions, or actions correspond element by element enables judgments of equality without requiring explicit counting. This capacity supports foundational mathematical concepts such as sameness, balance, and symmetry, and later underlies formal notions of equivalence classes. In weaving, pairing transforms perceptual and motor alignment into stable relational structure, illustrating how equivalence can be enacted materially before it is symbolized mathematically.

Figure 1. Maya woman weaving a symmetric motif on a back strap loom, Chiapas, Mexico (Photo by Rob Young, Wikimedia commons).

3.4 Memory and pattern maintenance

Memory, in this context, refers to the capacity to retain and update information about elements, operations, and intermediate states in order to guide ongoing behaviour (Núñez, 2009). In cognitive-science terms, textile production primarily recruits working memory and procedural memory, enabling the tracking of sequences, repetitions, and partially completed structures over extended periods of time. Rather than storing abstract symbols, this form of memory is tightly coupled to action, perception, and material affordances (Overmann, 2016).

Ethnographic accounts consistently report that weavers rely on memory to maintain complex patterns without external notation. In many traditions, patterns are “kept in the head” and executed through repeated cycles of movements that must be remembered across rows, bands, or panels of a textile. For example, backstrap weavers from central Mexico memorize long sequences of warp selections corresponding to specific motifs, often switching between multiple pattern registers within a single cloth (Gilsdorf, 2009). In Iranian carpet weaving, pattern execution frequently depends on recalling the number of passes or heddle lifts associated with each design unit, sometimes supported by rhythmic recitation or songs or poems that function as mnemonic scaffolds (Rafiepour & Moradalizadeh, 2022). Memory also plays a critical role in learning designs, planning the weave, and monitoring progress and detecting deviations from the correct chain of operations. Weavers often recognize mistakes not by visual inspection alone, but by a felt disruption of the expected sequence, indicating that remembered procedural structure has been violated (Maynard & Greenfield, 2003).

The role of memory in weaving is directly relevant to mathematical abstraction, as it supports the maintenance of ordered sequences and repeated structures across time. Retaining information about previous counts, groupings, and correspondences enables the extension of local operations into larger, coherent systems, an essential feature of mathematical reasoning (Núñez, 2009). Memory thus allows quantities and relations to persist beyond the immediate perceptual present. In this sense, memory is not merely a supporting capacity, but a constitutive component of numerical cognition, enabling repetition, accumulation, and the stabilization of patterned relations that later become formalized as arithmetic and geometry.

3.5 Exhaustion detection and completion

Exhaustion detection refers to the cognitive capacity to recognize when a finite resource, sequence, or process has been completed (Núñez, 2009). This capacity is understood as a goal-monitoring mechanism that allows agents to detect the fulfilment of a target quantity or the depletion of available material without necessarily relying on explicit counting. Exhaustion detection supports action planning, error correction, and the regulation of sequential behaviour.

In weaving and related fibre technologies, exhaustion detection is central to the successful completion of artefacts. Ethnographic descriptions frequently note how artisans know when a row, motif, or section of cloth is finished, even when the process is not accompanied by overt enumeration. For example, in warp-weighted loom weaving, completion is often recognized through the alignment of weft rows with predetermined structural markers, such as heddle positions or pattern boundaries (Bier, 2004).

Similarly, in basketry and net-making traditions, weavers detect completion when the final strand closes a loop, meets a starting point, or exhausts the allocated bundle of fibres. Weavers monitor the depletion of fibres by tracking how many rows, knots, or motifs can be completed with the remaining material. Weavers routinely monitor the remaining length or thickness of fibres to anticipate whether a motif or section can be completed without interruption (De las Peñas et al., 2014; Hirsch-Dubin, 2009; Pradhan, 2020). Among carpet weavers in Iran, for instance, the recognition that a colour run or yarn supply is nearly exhausted may trigger adjustments in pattern density or motif placement (Rafiepour & Moradalizadeh, 2022). In such cases, completion is assessed relative to both material constraints and intended design outcomes, reflecting an integration of perceptual cues, memory, and procedural knowledge . This form of exhaustion-detection relies on the ability to relate ongoing actions to an anticipated total.

From a mathematical perspective, exhaustion detection provides a powerful foundation for quantification by linking process termination to quantity. Recognizing that a sequence is complete or a resource depleted presupposes an implicit representation of a target amount, even if that amount is not symbolically encoded. This capacity supports the emergence of bounded sets, end-states, and totals, concepts that are central to cardinality and numerical abstraction. Practical engagements with finite materials and goal-directed action, highlight a pathway to quantification that precedes and complements explicit counting.

Table 1. Minimal cognitive capacities involved in weaving

Cognitive capacity	Cognitive description	Manifestation in weaving	Relevance for mathematical cognition
Grouping & unit formation	Segmentation of continuous material into discrete units	Bundling warp threads; grouping stitches or motifs	Basis for units, divisibility, and the treatment of quantities as countable entities
Ordering & sequential control	Maintenance of ordered action sequences over time	Fixed procedural steps; patterned repetition across rows	Foundation for ordinal structure, sequences, and algorithmic thinking
Pairing & correspondence	One-to-one or structured matching between elements	Mirroring motifs; aligning warp and weft; bilateral symmetry	Crucial for equivalence relations, proportional reasoning, and symmetry
Memory & pattern maintenance	Retention and updating of action-relevant information	Remembering pattern sequences; tracking progress across time	Stabilizes numerical and spatial relations beyond the perceptual present
Exhaustion detection & completion	Recognition that a finite sequence or resource has been fully used	Knowing when a row, motif, or material supply is finished	Enables bounded quantification, closure, and completeness conditions
Cardinality &counting (small numbers)	Tracking the number of discrete elements or repetitions	Counting threads, passes, knots, or pattern repeats	Supports transition from quantical perception to explicit numerical concepts

3.6 Cardinality and counting (small numbers)

Cardinality refers to the cognitive capacity to track discrete quantities through the successive enumeration of elements or actions, while cardinality denotes the understanding that the final count represents the quantity of the set as a whole. Cardinality and counting are seen as key components of numerical cognition, bridging approximate, action-based quantification and the explicit representation of number as an abstract property of sets (Núñez, 2009).

Weaving practices frequently involve both explicit and implicit forms of counting (often quantities up to five), even in the absence of formal numerals. Ethnographic accounts of loom weaving often describe how artisans keep track of the number of threads, crossings, or movements required to produce a given pattern.

For instance, in Indigenous American textile production traditions, weavers count knots or weft passes to ensure that motifs emerge at the correct scale and position (Franquemont & Franquemont, 2004; Gilsdorf, 2009; Hirsch-Dubin, 2009; Maynard & Greenfield, 2003). These counts may be expressed verbally, encoded in mnemonic aids, or maintained through embodied routines that associate specific gestures with numerical progression (Gilsdorf, 2009). Even before the weaving action, the construction or setting up of the loom also requires a strict chain of operations with its own sequence of actions (Bonilla-Tumialán, 2023; Maynard & Greenfield, 2003).

The mathematical relevance of cardinality and counting small numbers in weaving lies in their role in the transition from quantical to numerical cognition (Núñez, 2009). Through repeated engagement with discrete elements (e.g., threads, knots, crossings) quantities become stabilized as countable units that can be tracked, compared, and reproduced (Overmann, 2013). Weaving thus provides a material and procedural context in which number emerges not merely as an approximate magnitude but as a discrete, exact property of sets. By grounding numerical concepts in embodied action and perceptual regularities, fibre technologies may have scaffolded the abstraction of number from activity-based quantification to explicit numerical representation.

4. Discussion

Taken together, grouping, ordering, pairing, memory, exhaustion detection, and cardinality operate jointly to structure space through repeated, goal-directed interactions with fibres arranged in tensioned arrays. From these interactions arise grids, symmetries, and proportions, not as abstract templates imposed in advance, but as stabilized patterns produced through the recursive alignment of sequences, correspondences, and bounded quantities (Gerdes, 2003).

The warp-weft grid, for example, emerges from ordered crossings and paired alternations, while symmetry and proportion arise from correspondence relations and controlled repetition across finite spans (Ingold, 2016). Weaving thus exemplifies a form of spatial-numerical integration in which numerical relations are enacted spatially and spatial structures are regulated numerically (Bier, 2004). In this sense, textile practices offer a model for how geometric reasoning may develop from embodied, materially grounded operations that bind space and quantity into a single, coherent cognitive system.

These observations have broader implications for cognitive science, particularly for approaches that emphasize embodied, extended, and materially situated cognition (Lakoff & Núñez, 2000; Núñez, 2004). Fibre technologies illustrate how numerical and geometrical ideas can be scaffolded by recurrent interactions between bodies, tools, and structured materials, rather than emerging solely from internal symbolic manipulation. Weaving practices provide culturally stabilized environments in which fundamental cognitive capacities are repeatedly exercised, coordinated, and transmitted across generations, thereby supporting the gradual stabilization of numerical concepts.

At the same time, important limitations must be acknowledged. Cross-cultural and ethnomathematical accounts vary widely in terminology and analytical focus (Rosa & Orey, 2016), and some studies explicitly seek mathematical structure in craft practices, potentially projecting formal descriptions onto processes that makers themselves do not conceptualize in mathematical terms (Bender & Beller, 2011). In certain cases, mathematical operations may be rendered explicit through researchers' analytic frameworks or elicitation methods rather than through indigenous explanatory models (Pais, 2013). These caveats notwithstanding, the convergence of material, procedural, linguistic, and symbolic evidence suggests that weaving constitutes a powerful case study for examining how culturally embedded practices can afford and sustain numerical cognition, while also highlighting the need for reflexive, methodologically plural approaches in the study of implicit mathematics.

5. Conclusion

Weaving offers a single practice domain as a window onto general cognitive mechanisms. It combines action, perception, and abstraction, has cross-cultural depth, scales from simple operations to formal mathematical concepts, and has material persistence, which is crucial for cognitive offloading.

The aim of this paper is to synthesize abstract cognitive capacities (grouping, ordering, pairing, memory, exhaustion detection, and cardinality) across ethnographies of weaving, and relate those capacities to current cognitive theory of mathematics. Furthermore, it proposes that relations of grouping, ordinality, and equivalence could first emerge as materially enacted procedures in weaving practice before becoming formalized within symbolic systems of mathematical reasoning, thus bridging embodied action and formal abstraction.

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