PART TWO

Basketry as maths, pattern and engineering

INTRODUCTION

Stephanie Bunn

The relationship between basketwork and mathematics is arguably bound up with basketry's embodied techniques and practices, which develop and express informal geometric and numerical mathematical knowledge, from proportion, symmetry and spatial relationships to quantity, strength and time passing.

Such diverse techniques build rhythmically through repetition, creating patterns in the work, emerging at the interface of the maker's strength and that of the material. The force or tension captured in the ensuing folds, twists and knots holds the basket together, creating form and structure. For mathematician Ricardo Nemirovsky, the techniques and gestural moves in basketwork (and other crafts) articulate a form of bodily and mathematical understanding, where tangible geometric relationships are produced and revealed through movement, touch and engagement with the material, manifest also in the form of the finished basket. Maths, Nemirovsky suggests, has a physicality that can be explored through crafts such as basketwork – a significant insight in a world where learning has become increasingly abstracted and digitised.

The structural strength created through hand-twisting fragile plant materials such as straw or grass together is discussed by Ian Ewart in regard to Keshwa bridge construction, a feat of textile engineering renewed on an annual basis in the Andes. Artist Geraldine Jones also reveals the geometric aspects of basketwork through her looped wire structures, drawing on similar techniques to those used in Borneo looped-cane basketry. While she did not engage with mathematics as taught abstractly at school, she says, the practical engagement with materials and technique in basketwork has given meaning to geometric relationships, in similar vein to the mathematical patterns incorporated into African basketwork discussed extensively by Paulus Gerdes (1999).

Patterns and rhythms in basketwork link to time, counting and number as well as space and form, and are thus quantitative as well as qualitative. These temporal and spatial aspects of basketwork are synthesized in the spiral form of many basket bases, which parallels plant and animal growth patterns (including pine cones, sunflower seeds, nautilus shells. . .), as discussed by D'Arcy Wentworth Thomson, (1992). Like baskets, they grow, expanding in space from one end only – the centre – over time, and thus inevitably have this structure.

Artist Mary Crabb, reveals how the temporal, rhythmic aspect of basketry may embody memory. In *Significant Figures*, each knotted or twined strand is counted, commemorating the years passed since the death of her grandmother's former boyfriend, Cecil, in the First World War. Her knotted baskets quantify time. Andean *khipus*, knotted wool cord boards from the past as discussed by Hyland, have similarly been used to record reckonings such as debt. Hyland develops the numerical potential of *quipus* to consider how the direction of twine in the wool and its colour might also have had a narrative quality. The link between number, pattern and colour in basketwork is explored further by Hazelgrove-Planel in regard to 'mathematical literacy' through her experience of learning plaiting in Vanuatu. Here, colour gives a multi-layered dimension to patterning and geometric understanding.

Finally, Küchler reveals the relevance of knots and other forms of binding, as used in the topological branch of mathematics, for incorporating the capacity of social and political phenomena for self-organisation. She shows how binding in the Pacific is not so much symbolic, or representational, as revelatory of emergent social and political forms of order as diverse as kinship and kingship.

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7

On the continuities between craft and mathematical practices

Ricardo Nemirovsky

A pilot initiative exploring how to unveil and nurture new continuities between craft and mathematical practices has been a two-day Basketry and Anthropology workshop entitled *Tinkering with Curves*, that we organized at the University of St Andrews in April 2018, in partnership with two professional basket weavers (Geraldine Jones and Mary Crabb). A third basketmaker (Tim Johnson) participated in the workshop. The core idea was to use basket-weaving materials and techniques to create curves of different kinds and to investigate their variations. Participants included anthropologists, artists, architects and graduate students. By weaving willows, ropes and wires, participants crafted, with the support of the professional weavers, diverse pieces exhibiting families of curves. Figure 7.1 shows some of them. The subsequent presentation and discussion included topics such as curvature, smoothness, shadows and the poetics of curved lines.

Continuities between craft and mathematical practices must traverse old cultural-historical gaps secluding mathematics to intellectual and mental realms, devoid of physicality and materiality,

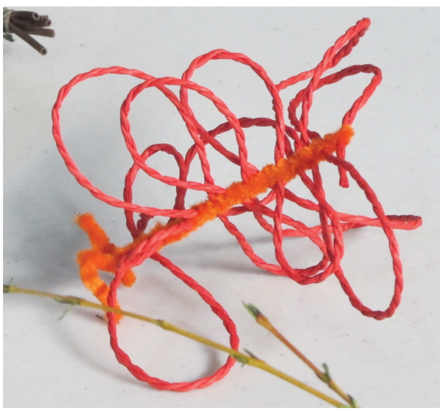

FIGURE 7.1 *Pieces woven in the 'Tinkering with Curves' workshop.*

and craftsmanship to affective and bodily techniques, lacking abstraction and theory. Do these continuities exist? How can we explore them? Mathematical analyses of decorative patterns, folk dances or music scores can be found in various strands of literature, and yet it is unclear whether these studies illuminate continuities with mathematics. Such uncertainty is fostered by the realization that these studies are not necessarily sources of new insights or developments in mathematics or crafts, arts and performances, beyond the notion that artisans and performers often unconsciously enact mathematical patterns.

A true continuity should be a source of inspiration for *both* craftsmanship and mathematics. A particular basketry practice from the South Pacific islands illustrates this point. 'All their baskets, small and large, are triangularly sixty-degree (three-way) woven, while all the basketry of all the rest of the world is square, or ninety-degree (two-way) woven.' (Buckminster Fuller 1981, 88). Figure 7.2 shows a pair of diagrams helping differentiate two-way and three-way weave. A triangular weave is stronger and more stable because horizontal strips are prevented from sliding upwards at points A and downwards at points B.

The stability of a triangular weave is threaded with the stability held by three struts joined by articulated joins on a plane (see Figure 7.3a). In contrast to the case of a quadrangle (see Figure 7.3b) — or of any figure joining more than three struts — each angle in the triangle is opposed by a single rigid strut, which ensures that these angles cannot change.

The fact that a triangle of sticks has a stability that no other planar figure has is a cornerstone of work in architecture, engineering and mathematics. It is deeply connected to the results that any three non-collinear points define a plane, and that a triangle is the simplest figure that can separate an inside region from its outside on a plane. These results can be generalized to any number of dimensions: the simplest stable structure that separates inside/outside in 3D space is a tetrahedron, formed by four triangles (see Figure 7.4)

The stability of a tetrahedron is derived from the stability of each triangle opposed to a vertex. Intertwining the strength and stability of three-way baskets with the ones of articulated triangles is an endless source of questions, which can inspire work in both, basket-weaving and mathematics. One can investigate, for instance, what kinds of spherical or oval balls can be woven triangularly, such as the ball shown in Figure 7.5. Basketry examples would have the potential to pose new

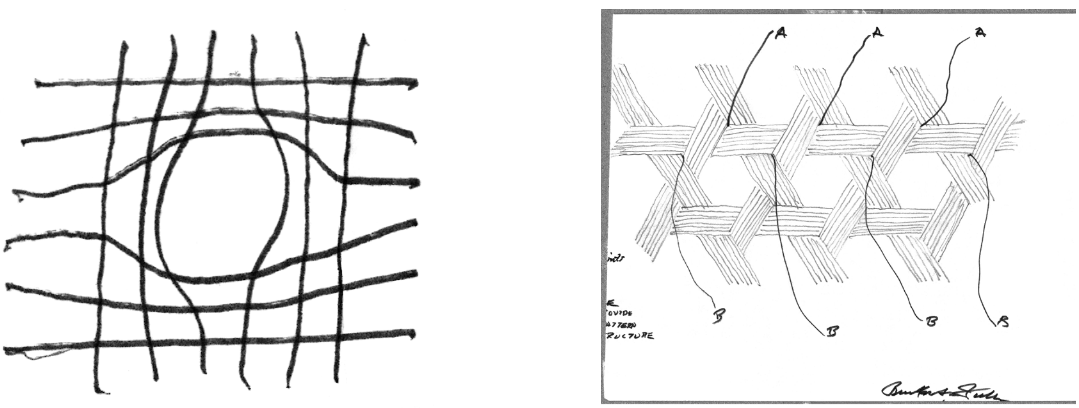

FIGURE 7.2 *Perpendicular and triangular weave, taken from* Critical Path *(Buckminster Fuller 1981, 89).*

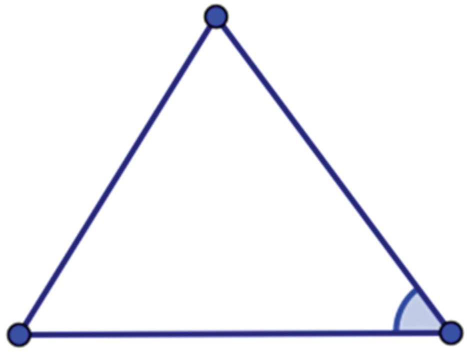

FIGURE 7.3a *Three struts connected by articulated joins on a plane.*

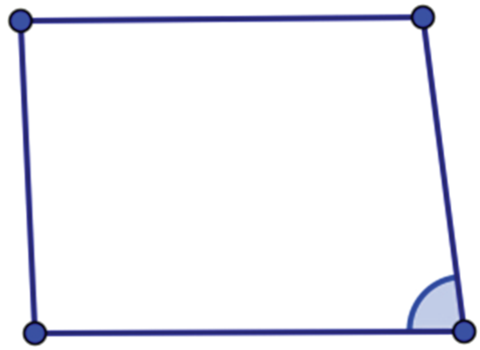

FIGURE 7.3b *struts connected by articulated joins on a plane.*

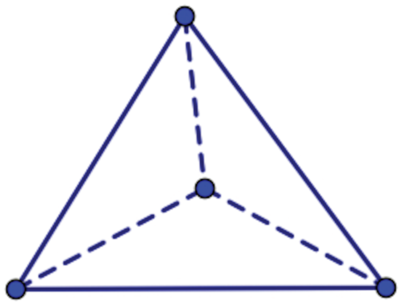

FIGURE 7.4 *The tetrahedron is the simplest figure bounding an interior region in 3D space.*

FIGURE 7.5 *Ball woven by Geraldine Jones.*

mathematical questions and mathematical insights could help imagine possibilities in basketry. This is what makes the search for continuities consequential. Furthermore, besides innovations in basketry and mathematics, continuities between them can help us grasp the cosmic and poetic significance of both practices.

Among philosophers working to elucidate the origins of geometry, Husserl envisioned the world of craft practices as an ancient ground in which geometry came to be:

> in the life of practical needs certain particularizations of shape stood out and that a technical praxis always aimed at the production of particular preferred shapes and the improvement of them according to certain directions of gradualness. First to be singled out from the thing-shapes are surfaces—more or less 'smooth,' more or less perfect surfaces; edges, more or less rough or fairly 'even'; in other words, more or less pure lines, angles, more or less perfect points.
>
> HUSSERL 1989

The gradual approximation to an unattainable archetype, such as polishing towards perfectly smooth surfaces or sawing near perfectly straight cuts, gave grounds to conceive of ideal shapes always differing from physical models and yet, related to them. While measuring the perimeter of a wooden circle cannot obtain the exact length of a corresponding ideal circle, it must not be far from it; furthermore, polishing the wooden disc and using more accurate measurement techniques would get even closer to it. Husserl (1970) argued that modern developments of science and mathematics have worked to forget these origins striving to purify[1] mathematics by detaching it from everyday worlds of practical and ethical concerns; in other words, continuities between craft and mathematical practices had been central during the ancient origins of the geometry, but afterwards they were hidden down into an abyss separating them.

These persistent efforts to purify mathematics appeared to restrict the tangible and bodily basis of our mathematical intuitions to the work of children and uneducated adults and led to the formulation of learning trajectories going from the 'concrete' to the 'abstract', depicting mathematics learning largely as a gradual dispossession of bodies, gestures, and performances towards distilled and decontaminated thoughts. The result is somewhat paradoxical: during mathematical work the presence of feelings, gestural movements and interactions with materials, including diagrams, are inescapable but all of these disappear from public accounts and published proofs. A background of life with materials and diagrams recedes onto an unspoken underground, supplanted by definitions presented as free-floating statements that can stand on their own. This suggests that Husserl's historical intuition about the centrality of craft practices for the ancient origins of mathematics has not gone away. Life with materials has always been and is crucial to mathematical development, but, subject to a process of discursive purification, it has been veiled out of sight. Unveiling this ground is necessary in order to trace continuities between craft and mathematical practices. I pursue this disclosure by striving to unpack the notion of *conversation with materials*.

'Conversation with materials' is a phrase associated, in my recollection, with the work of Jeanne Bamberger and Donald Schön (1983, 1992). The gist of its meaning, as I understand it, can be grasped in opposition to the conception of hylomorphism – a term derived from the Greek words matter (*hulê)* and form (*eidos* or *morphê)* – for the interplay between form and matter. According to the hylomorphic framework that can be traced back to Aristotle and ancient Greece, material objects are pieces of matter or substance – largely passive or inert – shaped by the active and external imposition of forms. Hylomorphism, which postulates an asymmetry between conformist matter upon which a design is inflicted or caused, has influenced widespread and prevalent images of fabrication, education and medicine. Simondon (2015) has elaborated an influential critique of the hylomorphic framework.

> A hylomorphic model, Simondon concludes, corresponds to the perspective of a man who stands outside the works and sees what goes in and what comes out but nothing of what happens in between, of the actual processes whereby materials of diverse kinds come to take on the forms they do. It is as though, in form and matter, he could grasp only the ends of two half-chains but not what brings them together, only a simple relation of moulding rather than the continuous modulation that goes on in the midst of form-taking activity, in the becoming of things.
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> INGOLD 2013, 25

Conversations with materials points at an alternative to hylomorphism by portraying the interplay between matter and form-taking activity as akin to the interaction between conversants jointly improvising, mutually thought-provoking and learning, as they pursue open-ended conversations that keep drifting from anticipated courses of action. Understood in this way, the notion of crafting as a conversation with materials is obvious to any craftsperson: far from imposing preconceived forms on passive materials, craftspeople are shaped by the materials as much as they shape materials, through an intertwinement suffused by improvisation, surprise, and mutual responsiveness.

Conversations with materials have had a marginal presence in the modern history of mathematical practices, particularly compared to the clearly predominant conversations with diagrams. Folding has been an example of a peripheral but mathematically significant conversation with materials (Friedman 2018). Ancient Greek mathematicians chose two instruments, straightedge and compass, as the only means apposite to use for the development of theorems in geometry besides textual ones. '[Euclid] however, employed a fourth tool without accrediting it – this was the surface upon which he inscribed his diagrammatic constructions' (Buckminster Fuller, cited in Krausse and Friedman 2016). The materiality of surfaces amenable to sustain perdurable inscriptions, such as parchment, papyrus and paper, is capable of sustaining powerful conversations, which include folding. A remarkable outcome of folding a piece of paper is that it obtains a straight line. The straightness of a folded crease is an expression of the materiality of paper interwoven with skillful actions of hands and fingers over time. That skillful actions and material engagements are temporal processes is a crucial element in the course of conversations with materials. Thinking of lines as emerging from acts of drawing or folding intertwined with active materials that resist, guide, entice or block, rather than preexisting entities that appear already formed or completed without history and genesis, has profound implications in all realms of life (Ingold 2007), including mathematics:

> We find experimentally that two lines cannot go through the same point at the same time. One can cross over or be superimposed upon another. Both Euclidian and non-Euclidian geometries mis-assume that a plurality of lines can go through the same point at the same time.
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> BUCKMINSTER FULLER, cited in KRAUSSE and FRIEDMAN 2016

Try to draw two straight lines with a pencil in each hand: close to the time of the intersection one of the pencils will block the other one from reaching the overlapping intersection point. An equivalent result is obtained with two folds since they cannot be folded simultaneously around the intersection. Occasionally, folding became a powerful metaphor for the foundations of mathematics, such as in this remark by Leibniz:

> the division of the continuum must not be considered to be like the division of sand into grains, but like that of a sheet of paper or tunic into folds. And so although there occur some folds smaller than others infinite in number, a body is never thereby dissolved into points [. . .] It is just as if we suppose a tunic to be scored with folds multiplied to infinity in such a way that there is no fold so small that it is not subdivided by a new fold [. . .] And the tunic cannot be said to be resolved all the way down into points; instead, although some folds are smaller than others to infinity, bodies are always extended and points never become parts.
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> LEIBNIZ, cited by FRIEDMAN 2018, 385

Folding has also been a source of new insights and developments across mathematics and crafts. The work of David Huffman – a computer scientist who became a practitioner of origami – illustrates this continuity: 'One of [his] discoveries was the critical "pi condition." This says that if you have a point, or vertex, surrounded by four creases and you want the form to fold flat, then opposite angles around the vertex must sum to 180 degrees' (Wertheim 2004 June 22). The aftermath of Huffman's work includes not only new theorems, but also the development of new origami approaches, including the use of curved folds (e.g. https://blog.kusudama.me/2017/09/24/origami-tools-curved-folding/). It is critical that this work is not a matter of applied mathematics; in other words, it is not about using certain mathematical results to design innovative pieces of origami, but about working out continuities originating new mathematics and origami. In one of their papers about the mathematics of folding, two mathematicians expressed such merging of mathematics and paper folding as they invited the readers to perform an experiment:

> draw a curve on a sheet of paper and slightly fold the paper along the curve. A word of practical advice: press hard when drawing the curve. It also helps to cut a neighborhood of the curve, for it is inconvenient to work with too large a sheet. A more serious reason for restricting to a neighborhood is that this way one avoids self-intersections of the sheets, unavoidable otherwise.
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> FUCHS and TABACHNIKOV 1999, 28

I focused on folding to illustrate the presence of conversations with materials in mathematical practices and how they have fostered continuities with craft practices. Various other examples could have been chosen for this purpose, such as the historical roles of linear perspective for the emergence of renaissance art and projective geometry, or the use of mechanical devices to draw curves during the sixteenth and seventeenth centuries for both, design and study of mathematical functions. Contemporary instances, such as fractals, molecular synthesis and system dynamics, suggest that conversations with materials tend to be less marginal in mathematics than they used to be. Conceivably, as compared to the mathematical ethos of a century ago with its almost exclusive orientation towards formalism, nowadays mathematics is gradually embracing materiality (de Freitas and Sinclair 2014) and movement (Ferrari 2019).

Through initiatives such as 'Tinkering with Curves', we envision the creation of studios in which participants engage in craft and art projects, explore mathematical themes, and share experiences in partnership with mathematicians, craftspeople, artists, architects, anthropologists and educators.

NOTE

1 I use the term 'purification' in ways that are akin to how Latour (1993) uses it in *We Have Never Been Modern.*

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