OBJECTS OF LEARNING

An Anthropological Approach to Mathematics Education

◆ **GRAEME WERE**

University College London

Abstract

Over the last two decades there has been a proliferation of studies in ethnomathematics dedicated towards shedding light on its importance in enhancing education (cf. Bishop, 1988; Gerdes, 1985). Many ethnomathematicians have utilized the object world as a tool in the learning of mathematical concepts, but little research to date has focused on the role of objects as agents that activate mathematical thought. In this article I argue that the material qualities of objects can mobilize mathematical thinking and act as vehicles for learning. I show that geometric patterns incised on traditional arts and crafts are effective tools in the mathematics classroom in cultures that tend towards visual forms of knowledge. Anthropology is ideally suited for this type of study and as I aim to show, an ethnographic approach can give valuable insights into education and knowledge technology.

Key Words ◆ material culture ◆ mathematics education ◆ Papua New Guinea ◆ pattern ◆ thought

ANTHROPOLOGY, MATHEMATICS AND LEARNING

Pattern – the process of carving, incising, painting or etching regular geometric shapes on the surface of an object – has given rise to some of the most flamboyant creations of human imagination and skill ever seen. As a geometric form of art, pattern embodies mathematical principles[1] – a series of symmetrical transformations involving co-ordinate changes along a plane: reflection, rotation, translation and glide reflection (see Figure 1). Pattern also has a tendency to evoke a range of emotional and personal types of thoughts, as well as being significant in the constitution of personhood and cultural identity (Küchler, 1991; Morphy, 1991).

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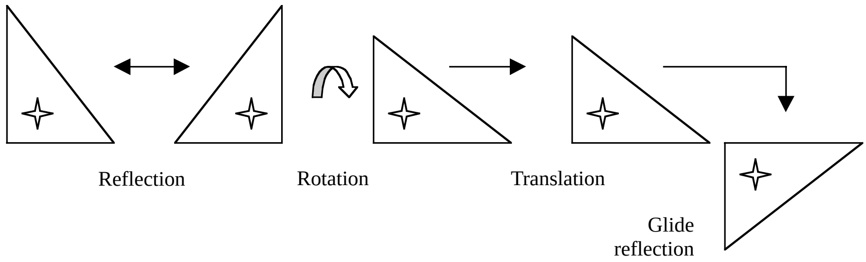


FIGURE 1 Symmetrical transformations: reflection, rotation, translation and glide reflection.

Traditionally anthropology has relied on producing design books rich in visual imagery and description whilst ignoring the dynamics of pattern. Recently, Jewell and Lloyd (1998) and O'Hanlon (1989) all describe the panoramic style of pattern and design innovation within Pacific culture though no research to date is directed towards how knowledge of pattern is generated and reproduced as carrier of thought of a particular kind.

Although most research into pattern and geometry has been carried out in the field of education, three approaches exist in anthropology that address the construction of spatial and numerical knowledge. The first perspective focuses primarily on socio-historical processes in the construction of knowledge. One example is a study on the learning of social hierarchy in the South Pacific nation of Fiji. Toren (1990) examines the acquisition of spatial relations and categories in social practice, evinced in the *kava* drinking ceremony. She states that a person's concept of hierarchy is related to spatial reference points during *kava* drinking. The positions in which persons acquaint themselves spatially are concretized through reference points within buildings and the ritual space. Toren states (1990: 2) that 'persons are at the same time both products and producers of . . . group processes'. She demonstrates that ideas about hierarchy are constructed temporally in social processes and manifested through sociality (1990: 17). Utilizing drawings made by children, Toren shows that representations are by no means ready-made but take shape in practice.

The second approach is by cognitive anthropologists who explore the acquisition of cognitive skills in a specific context, called 'situated learning'. In one study, Saxe (1991) examines the mathematical performance of street children in Brazil who sell confectionery for a living. He found that children developed cognitive styles that are specific to the mathematical and spatial problems encountered in everyday life, so as trade prices of sweets fluctuated, children made new calculations of unit price. Rival confectionery sellers also meant that children had to adapt their unit prices to compete with special prices on offer by rival sellers. Tests showed that the street children were able to outperform their school counterparts on all of the mathematical tests by presenting them the problem in material form, i.e. with confectionery boxes. The same street children could not perform the task on pen and paper, showing that unit price calculations were tied to the social processes that constitute everyday street life. A similar process is described by Lave (1988) in a study of supermarket shopping. Lave shows that persons acquire mathematical skills while assessing best-price deals in supermarkets. In the classroom, the same calculations cannot be reproduced successfully by shoppers, suggesting that objects and mathematical thought are inseparable from the experiences of everyday life.

A third approach explores pluralistic ways of knowing. Inspired by new computing technologies, Turkle and Papert (1990) assert that there can be no one way of knowing. Instead, people employ pluralistic modes of thought to arrive at conclusions and representations. An example of this is by Wassmann (1994) in which he states that the Yupno of Papua New Guinea employ three different ways of spatial perception. Whereas western concepts of space are ego-centric, the Yupno use object-centred locations such as relative positioning, absolute positioning (north, east, south and west) and anthropomorphic projection to locate themselves in space. These may be employed at different times and are context dependent.

The three perspectives focus on the social and cognitive processes in the construction of mathematical knowledge whilst ignoring the material quality of objects, offering little in the way of explanation as to why these objects are influential in mobilizing cognitive processes involved in learning. So what then are the qualities of objects that facilitate a high level of mathematical performance with learners of little or no formal education?

MATERIALITY AND THOUGHT

Papert (1980) describes processes of ‘thinking with objects’ as ‘concrete thinking’. These processes include both cognitive and affective criteria. An object describes certain physical properties that in principle, anyone might recognize. But in order for a person to actively think with it, the object must relate to individual experience through various syntonicities – of body, ego, and/or culture. Though many objects might embody potentially interesting physical characteristics, there is no guarantee that they will connect with more personal aspects of thought. Certain objects may be more or less likely to touch ‘affective’ aspects of people’s lives. Therefore in material culture, anthropologists have focused on the materiality of the object as a synthesis of thought process. An example of this is Strohecker (1991) who states that when people think about knots, they think about many things at the same time. Knots are everyday objects which evoke a range of emotive feelings. Not only do they embody mathematical principles, but a whole branch of mathematics 'knot theory' is dedicated to the study of them. Strohecker (1991) says that the practice of tying knots by children elicits a range of experiences and emotions relating to what she calls 'topological thought'. As children become familiar with tying knots and the string with which they use to tie them, memories become evoked and elicited in the process. Thus, the complex surface of the knot engages the mind, engendering relations between object and person (cf. Gell, 1998, on patterns and mazes as mind traps).

A similar phenomenon is described by Wassmann (1991). He examines the *kirugu* knotted cord in the Sepik region of Papua New Guinea. During ritual performances, a village elder passes the *kirugu* knotted cord through his hand, enabling him to recall and recite ancestral names during clan song cycles. As the holder's fingers move along the cord, the fingers feel small and large knots, mnemonic devices for the interjection of clan stories during ancestral song recitals. The knotted cord is thus an active surface forging a relation between material object and mental process through the movement of the hand as it feels its way along smooth spaces and knotted contours, generating responses from the holder of the cord.

Perhaps one of the most useful contributions to the relation between mental and material processes in the field of anthropology is the work of Susanne Küchler. Recently Küchler (2001) has extended her work on art and aesthetics in New Ireland by concentrating on the art–mathematics nexus through knotting and binding. Here, she demonstrates how knotting and binding technologies are implicated in spatial reasoning – the New Ireland malangan funerary sculpture, the Hawaiian sacred knotted cord, and sculpted knot-spanning surfaces – all describe how the generation of knotted artworks is an intuitive device to conceptualize the world. Küchler's work offers insights into material and mental processes that help shape intellectual creativity and implicate not just knots but a wider understanding of the relation between material culture and thought process.

These cases clearly illustrate a relationship between materiality and mathematical thought, yet pattern remains a problem. Anthropologists and ethnomathematicians continue to treat it as though it were decorative art, denying it efficacy in animating thought by reducing it to mere surface decoration. However, a recent development in mathematics education in Papua New Guinea challenges this assumption made about the role of pattern – which sees a shift from a language-oriented curriculum programme towards an object-centred learning initiative, utilizing pattern found on local arts and crafts.

STUDIES OF COGNITION AND MATHEMATICS IN PAPUA NEW GUINEA

Papua New Guinea (PNG) is an ideal place to situate a study into mathematics learning as learners' performance has long been considered to lag behind counterparts in western countries. Cognitive tests have shown that children in places like PNG acquire spatial skills at a later age than their western counterparts. Another reason is that educationalists have assumed mathematical knowledge to be acquired formally in the classroom rather than in everyday practice (as the examples given earlier illustrate). So in an attempt to explain poor mathematics results by students in PNG, many studies have been carried out over the last 20 years to investigate this issue. The most important of these is the Indigenous Mathematics Project.

Set up in the 1980s, the Indigenous Mathematics Project explored a variety of learning experiences in an ethnically and linguistically diverse country.[2] Its primary concern was to explore diversity in cognitive development and to study children's learning of western mathematics (Lancy, 1980). Mathematical tests were conducted over 10 cultural regions, all administered in the local vernacular. The range of ethnolinguistic groups employed in the study aimed to exploit the differences in indigenous thinking and assess whether local counting systems played a significant role in this. Research was directed at cognitive, environmental, social and linguistic factors that could be attributed to differentiation in cognitive ability.

In a book published on the findings, the Project was critical towards the existing education curriculum at the time (Lancy, 1983). Language proficiency was found to be a crucial factor in the mathematical performance of school children. Elementary school children found it difficult to develop mathematical skills in English, when their grasp of the English language was by no means proficient: English was a second language for the majority of children. Souviney (1981) points out that many PNG school children were confused by the way in which the syntax is used in expressing mathematical terms; there are numerous ways to express simple terms such as five minus four, five subtract four, five less four, subtract four from five etc. The project led to a series of papers exploring spatial ability, mathematics performance and learning in Papua New Guinea society (e.g. Ausburn and Ausburn, 1982; Lean and Clements, 1980).

Today, research in mathematics education has clearly had an impact on the present design of the education system in Papua New Guinea. A new Centre for Ethnomathematics has been set up at the Institute of Education by the University of Goroka which aims to record and document the rich variety of mathematical counting systems indigenous to the many diverse cultures in the region. At grassroots level, curriculum innovation now sees elementary school children learning mathematics in the local vernacular, and basic mathematical skills such as geometry and numeracy being taught in the context of the local culture. Pattern now also features at the centre of this new elementary school programme.

PATTERN AND THE NEW PAPUA NEW GUINEA ELEMENTARY SCHOOL CURRICULUM

The new elementary school curriculum is designed to enhance learning by exploiting a child's existing knowledge of local traditions.[3] This initiative seeks to make use of local knowledge utilized in the village community, believing that the knowledge required in say basketry, can be applied to the western mathematics programme in local schools to function as a concrete link between abstract mathematics and local everyday life. It is based on the theory that certain properties of objects can harness mathematical thoughts, and it is these thoughts that can be used fruitfully as a vehicle for learning. So for example, concepts of numeracy and spatial reasoning are tapped directly from the mathematics embedded in various phenomena with shape, symmetry, time, pattern, colour, set theory, number, angle length, and capacity illustrating some of the specific mathematical concepts the curriculum programme harnesses. The programme also utilizes mathematics through the performative aspects of culture: traditional dance (drumbeats and movement); traditional music (rhythm and timing); and traditional arts and crafts in the teaching of pattern, shapes, and designs. The focus on visual and material culture in the curriculum emphasizes the concreteness of the learning experience utilizing students' familiarity with objects and materials, concepts and cultural practice.

The design of the curriculum is implemented on a national scale but the curriculum content is formulated locally by a group of teachers and planners employed in each region of PNG. A specially designed guide helps local teachers and planners assess the aims of the curriculum and find practices, skills and ideas within their local culture which will help children fulfil the national educational objectives, a process that may involve liaising with knowledgeable men and women in the local community. A series of suggestions guides teachers to asking some basic questions about pattern (see Figure 2).

The onus placed on local teachers to design the content of the curriculum using local knowledge systems alleviates any critiques levied

Who in the community has knowledge of the traditional patterns and designs?
What are the traditional patterns and designs?
Why do we use traditional patterns and designs?
When do we use traditional patterns and designs?
Where do we use traditional patterns and designs?
How do we draw traditional patterns and designs?
Here are two examples from Ovatoi village in the Trobriand Islands, Milne Bay Province.

Example 1
Who? Sobububwaluwa.
What? Traditional carving designs.
Why? Sobububwaluwa uses these designs in his carvings because they are attractive and catch the people's attention.
When? These patterns are used when new canoes are cut and on new carvings to be sold to tourists.
Where? They are traditionally used on the prow boards and on the rear of the village canoes. These patterns are also used on the yam houses, and the chief's dwellings.
How? These are carved with special carving knives and chisels. Another special tool used is called the ligogu in the Kiriwina language.

FIGURE 2 Pattern as a tool for teachers in Papua New Guinea.
(Source: Elementary Education: making your own community curriculum. A guide for elementary trainers and teachers. Department of Education, Papua New Guinea 1999: 5)

against it that may accuse the curriculum planners of favouring key cultural groups in Papua New Guinea, such as Highlanders or Sepiks. It also tackles the problems thrown up by colonial education – a system using Australian mathematics textbooks – by placing local culture and language at the centre of study, thereby dismissing any suggestion that mathematics learnt in the village is irrelevant to the experience of everyday life (see Kari, 1998 on the kind of problems distance education learners experience in PNG). In addition, the use of local language in the classroom no longer means that elementary school children require working knowledge of English (cf. Lancy, 1983). By encouraging the exploration of local knowledge systems to teach western mathematics, the curriculum is not therefore susceptible to the kind of critique that Verran (2001) puts forward in Nigeria, where local and western mathematics are taught in parallel, producing in effect an apartheid education system. Local people in Papua New Guinea are extremely proud of their local traditions, so by studying the social life of mathematical concepts (cf. Verran, 2001), it reinvigorates interest in local traditions and provides

1. Look at the walls of the houses in your community. What patterns do you see? Draw them.
2. Look at the material of the clothes you are wearing, what patterns can you see? Draw them if you can.
3. Look for patterns in the things made in your community. Make a list of the things and draw the patterns. If you can you should collect items with different patterns on them.
4. Were all pigs which are now adult, baby pigs once?
5. Were all butterflies baby butterflies once?
6. How many different life cycle patterns can you think of?
7. How many different patterns can you see in the things around you?
8. Numbers can also be arranged in patterns. The numbers in counting order form a pattern made by adding one to the last number. Write down the pattern made by adding two to the last number.
9. Does it matter which number you start with?

FIGURE 3 Learning pattern in the local environment.
(Source: Cultural resource book for mathematics. Trial version. Department of Education, Papua New Guinea 1999: 27)

a tangible link between what is learnt in the village and how it relates to the outside world.[4]

The new mathematics programme places pattern at the forefront in learning mathematical concepts and its central position in the curriculum suggests again the efficacy of pattern in Melanesian society. Curriculum planners link the generation of pattern to spatial reasoning, the creation of local arts and crafts (weaving and basketry), number sequences (e.g. 1, 2, 4, 8 ...) and colour patterns (mosaics), seasons and time, and its role in performances where it is implicated in rhythm in music and dance formation.[5] Pupils are encouraged to explore their environment to find different shapes and patterns, experience different materials and to think about the names in their local language. They are challenged to find names for geometric shapes for patterns woven into local mats and baskets and also fishing traps, house structures and cooking pots. Curriculum activities encourage the teachers to show pupils how to make patterns with objects, eliciting from the pupils underlying rules for the patterns, and classroom discussions are aimed at observing and repeating traditional performance and reproducing local arts and crafts.

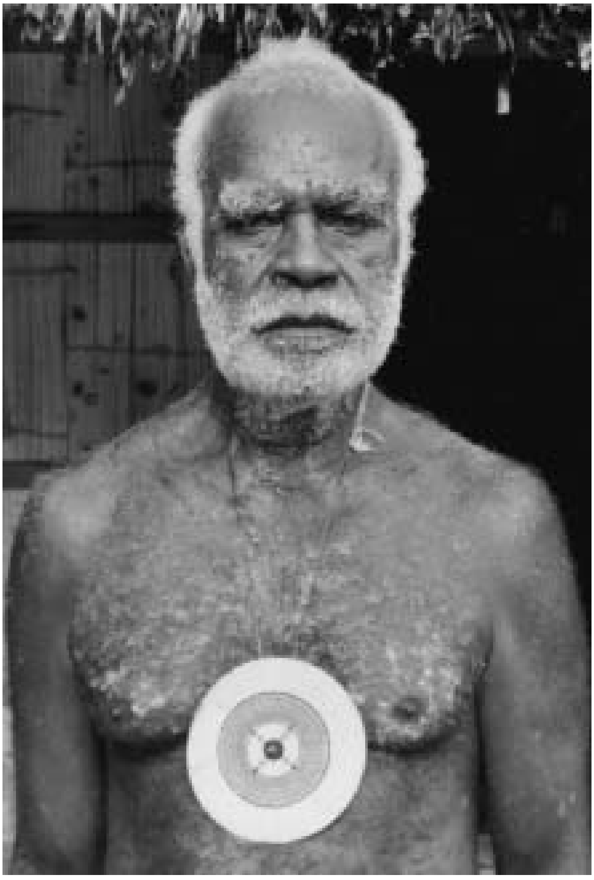
The implications of the education initiative clearly explicate a link between learning and the object world. It shows that activities such as basket-weaving, cloth making, or the carving of wooden artefacts all mobilize mathematical thought in their creative or performative roles.

So with pattern elevated to a prominent position in the curriculum, what are the qualities that make it so effective in mathematics learning? I explore this now by examining the patterned-shell valuable, the *kapkap*, from northern New Ireland**,** Papua New Guinea.

THE CASE OF THE PATTERNED-SHELL ORNAMENT, *KAPKAP*, FROM NEW IRELAND

Kapkap is the name of a circular composite shell ornament found across Western Island Melanesia that comprises of two key components: a shiny circular backplate made from rubbed-down clam shell and a turtle-shell plate, into which intricate designs are incised, engineering an effect like a paper doily (see Figure 4). The turtle-shell fretwork rests on top of the

FIGURE 4 Man wearing kapkap, Munawai Village, New Ireland.



clam shell disc, and the two components are fastened together by a shell string that is threaded through a centre hole of the clam shell and turtle-shell, the end of which is knotted. The decoration is worn around the neck like a medal or medallion, the disc resting on the breast of the wearer. Museum collections sometimes refer to the *kapkap* as a breast-plate, though this is misleading since in the Solomon Islands, *kapkaps* are sometimes worn on the side of the head (see front cover of Burt, 1981).

The most salient features of the *kapkap* are the patterns incised into the turtle-shell disc.[6] The patterns appear as regular incisions, almost moving and dancing around the concentric bands that appear radiating out from the centre of the design. A large cross-like motif is carved in the centre of the pattern, surrounded by a number of concentric circles, filled with geometric shapes and symbols, often compared to hiero-glyphics or runic symbols. On closer inspection, the symbols are regular motifs that are repeated in radial fashion, intricately carved and proportionally precise. Triangles, diamonds, parallel lines and tooth-like motifs are among many designs that are incised with incredible regularity into the turtle-shell, almost with machine-like accuracy. The precision of the craftsmanship is alluring. Little wonder that so many of these ornaments were collected by western explorers in the 19th and early part of the 20th century.

In the Nalik region of northern New Ireland, a matrilineal society comprising of around 4000 Austronesian speakers, *kapkaps* are worn by clan leaders, '*maimai*', at mortuary feasts, giving them the right to speak on behalf of a clan they represent. At an elaborate initiation ceremony held at a mortuary feast, a '*maimai*' may be presented with the right to speak for a clan. Over time, as a '*maimai*' attains more rights, the *kapkap* pattern grows in surface area as it is re-carved, incorporating an extra concentric band for the new sets of rights attained. Each band in the pattern signifies the number of clans a '*maimai*' can speak for. In turn, the more rights a '*maimai*' acquires, the wider his social scope becomes, entitling him to speak in more and more village hamlets. The pattern on the *kapkap* thus becomes a means to legitimize the status and social encompassment of a '*maimai*'.

THE NEW IRELAND SYSTEM OF STYLE

The formal properties of the New Ireland *kapkap* pattern consist of a series of concentrically arranged circles that emanate out from a large central cross motif. Inside each of the circular bands, motifs are repeated in rows and aligned with motifs in adjacent bands. Around 14 different motif forms make up a 'corpus of motifs' specific to New Ireland, though it should be noted that each pattern exhibits only two or three types of motif rather than the complete corpus.

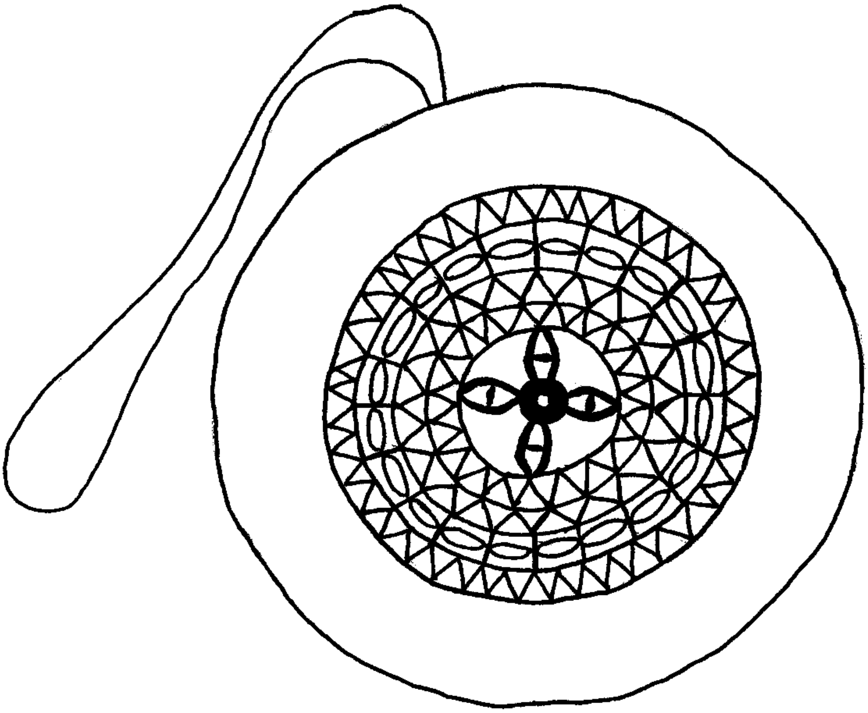


FIGURE 5 Detail, New Ireland kapkap.

The *kapkap* is particularly useful in teaching geometry and number for the array of spatial operations and counting procedures that are generated in the pattern. Take for example, the typical New Ireland *kapkap* (see Figure 5). The pattern has a large central motif exhibiting bilateral and rotational symmetry with four concentric circles radiating out from the central hole. A zig-zag motif is applied inside the first (outer) concentric band, repeating itself 40 times in total. The next band sees the application of a chain-like motif. Here, each chain-like motif corresponds to two zig-zags in the outer band. In the third concentric band, a one-to-one correspondence exists between the chain-like motif and the zig-zag motif, and again in the fourth band, one-to-one correspondence is maintained with the zig-zag reflected along the plane so that in total, 20 are carved inside each of the inner concentric bands.

The patterns are uniform throughout northern New Ireland, suggesting that stress is placed on stylistic coherence and accounts for the way patterns are recognized as ‘coming from New Ireland’. Minute stylistic variations make individual *kapkaps* recognizable though these differences are difficult to notice. So by formulating a system of parameters

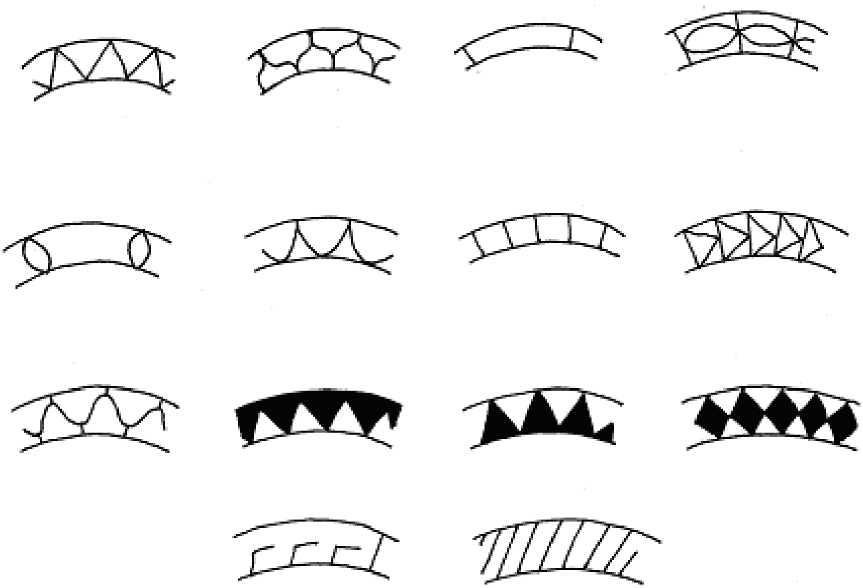


FIGURE 6 The New Ireland corpus of motifs.

that defines New Ireland art style, we can begin to account for the quality of pattern that induces mathematical thought process.

An overview of style for the New Ireland *kapkap* has indicated a close resemblance between the various motifs in the corpus. Furthermore, if we compare the motifs with each other, there appears to be a series of transformations that allows one motif in the corpus to become another motif. They are: reflection and rotation along the plane (cf. Washburn and Crowe, 1988); and linear – radial transformation, i.e. a straight line in a motif is transformed into a curve, or vice-versa. This preliminary visual analysis confirms a system of relationships between the motifs inside the corpus. An outcome of this is that every motif in the corpus can be generated from any of the other motifs inside the corpus, so that the corpus derives from any one singular motif. The New Ireland corpus of motifs is illustrated in Figure 6 while an individual motif's relation to the corpus of motifs features in Figure 7:

Zig-zag motif – The zig-zag motif consists of a sequence of triangles that point outwards from the centre as well as inwards towards the centre. For the sake of the analysis, I describe how all the other motifs are generated from this motif.
Tile motif – The form of this motif is generated by taking the zig-zag motif and transforming the two sides of the triangle shape into reverse S-shapes.
Wave motif – The form of this motif is generated by a transformation of the sides of the zig-zag to parabolic curves.

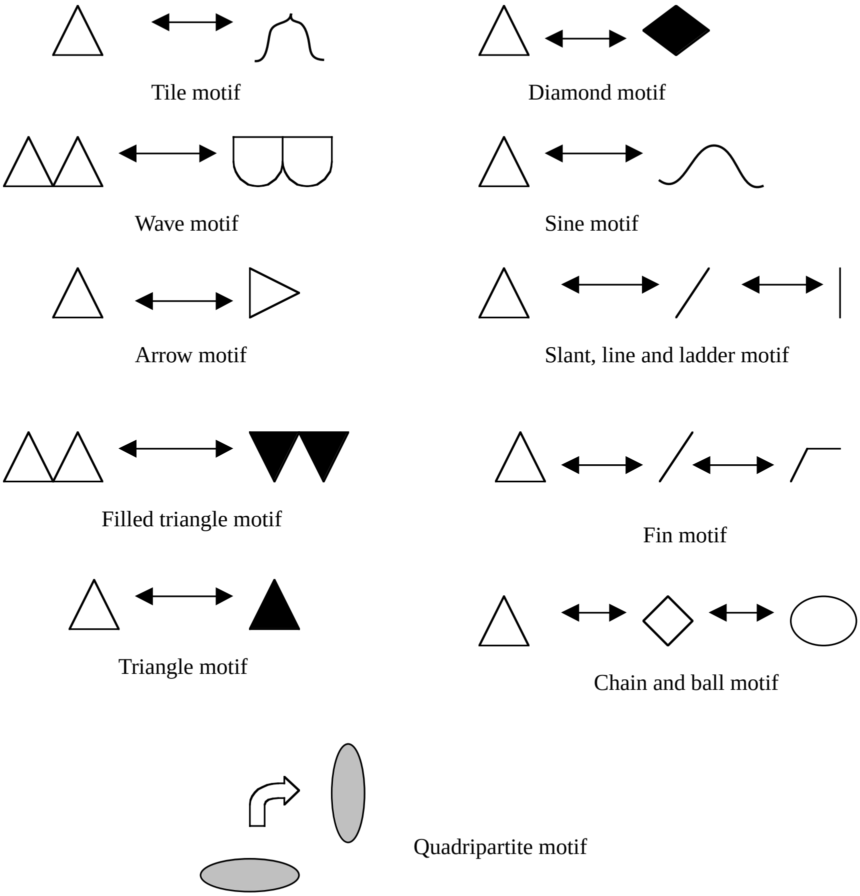


FIGURE 7 Motivic transformations.

Arrow motif – The formal qualities of this motif can be generated by taking the zig-zag motif and rotating the triangle shape through 90 degrees to the plane.
Sine motif – The motif is generated by transforming the sides of the triangle into S-shapes.
Filled zig-zag motif – This motif is generated from the zig-zag motif and involves cutting out a small triangle from the base of the concentric band, producing a figure-ground reversal effect.
Triangle motif – The form of this motif is generated by taking the zig-zag motif, but instead of removing the small inner triangle, this extracting process is ignored: i.e. no turtle-shell removed.
Line motif – The form of this motif is produced by taking one half component of the zig-zag and rotating the side of the triangle so that the line stands perpendicular to the plane.

Ladder motif – This motif is similar to the 'line' motif except that the vertical lines appear at regular intervals inside the concentric band.
Chain motif – The motif is generated by taking the zig-zag motif and reducing it in scale before reflecting the triangle shape along the plane. The four sides of the two triangles are then transformed into arcs, thus forming a circle or ellipse. A 'ladder' or 'line' motif may be appended to border the elliptical shape.
Ball motif – The generation of the motif relies on reflecting the zig-zag motif along the plane, followed by a transformation of the sides into curves.
Diamond motif – The formal design is generated by reflecting the zig-zag motif along the plane and transforming the scale of the diamond shape so that it fits between the concentric circles in the pattern. Conversely, the motif may be generated from figure-ground reversal, where two scaled down rows of zig-zags applied inside the concentric band are reflected along the plane, thus forming a series of diamond motifs.
Fin motif – The formal design can be generated by truncating a zig-zag so that one-half of the motif remains. Then, the side of the triangle is rotated at an angle at its midpoint so that it rests parallel to the plane. In the *kapkap* pattern, an occasional vertical line separates rows of the motifs.
Slant motif – The motif is generated in a similar fashion to the 'ladder' motif, whereby the zig-zag device is truncated and the resulting half of the triangle is aligned in rows.

A large quadripartite motif in the centre of the pattern resembles a star or cross with four points, but occasionally the motif is treated with five or eight points, all generated by rotating a point of the star-shape.

The objective of analysing all the transformations in New Ireland *kapkap* patterns is to demonstrate how individual motifs can be transformed into all others, thus generating the complete range of designs that I called the New Ireland 'corpus of motifs'. The complete set of motivic transformations accounts for all possible stylistic variations in *kapkap* patterns and dictates the principles that govern the creation of a pattern, enabling a *kapkap* to be recognizable as coming from New Ireland. These principles that govern the generation of individual motifs are constraints that are imposed on the possibility of transforming any motif in the corpus to any of the others. In other words, something belongs to New Ireland only if a motif can be transformed into another motif inside the corpus in accordance to the principles.[7]

The generation of style as a sequence of 'relations between relations' clearly demonstrates the argument set out by Gell (1998) on style and the artefactual domain, in which he shows that style is an autonomous, self-generating domain, only definable in terms of the relationships between artefacts and other artefacts (1998: 216). Here too, I have demonstrated how New Ireland pattern style is an autonomous system with the dynamic ability to generate itself from its own parts (see Saunders, 1997 for a description of non-linear autonomous systems).

This means that by taking any one motif in the corpus, the complete stylistic range can be generated.

The next stage of the stylistic analysis is to investigate the implications in conceiving of style as an autonomous domain. To answer this, we need to begin by first examining these 'relations between relations' that govern New Ireland style – the axes of coherence – and then we can begin to explore how this system could relate to other systematic properties of culture.

The formal analysis of pattern showed that a system of transformations governs the formal properties of motifs. These are as follows:

- Symmetrical transformations of motifs and part-motifs, including reflection and rotation.
- Scaling of individual motifs, such as halving the proportions so that the transformed motif fits inside the concentric circles.
- Co-ordination transformation from straight line to curved line and vice-versa (for example, the transformation of a diamond into a circular-shaped motif).
- Figure-ground reversal (i.e. the motif is generated from the negative space between the turtle-shell overlay and clam shell disc beneath).

This list of transformations covers all the possible motivic forms that are generated in New Ireland *kapkap* patterns and it would be reasonable to argue that this transformational system is unique to the New Ireland *kapkap*. It demonstrates that artistic style is founded on connections between the various *kapkaps* in the sample, since this list of transformations can only be generated by examining all stylistic forms inherent in the *kapkap*.

As the list stands, a basic trend can be sensed that inter-links the transformation of one motivic form to another. This logic derives from a structural principle that Gell calls in his formal analysis of Marquesan art 'the principle of least difference' (1998: 218) – a stylistic feature which draws out the relations between the elements that make up the overall style of an artwork. He uses this concept to explain the limited diversity in motivic transformation that enables an art style to become coherent and recognisable.

In the context of New Ireland pattern style, we can use this abstract principle to account for the generation and application of carved motifs inside the *kapkap* pattern. This structuring principle becomes evident if we see how motivic transformations occur with the least possible modification. Take for example the carving of a pattern with two concentric bands. If the zig-zag motif is carved in the innermost band, the principle of least difference dictates that the following motif in the outermost band should be a transformation of the first motif by reflection or rotation along the plane or by following a scaling procedure.

This system of style – governed by the 'principle of least difference' – accounts for slight variations in the composition of the pattern, allowing for small differences between *kapkaps* while at the same time remaining within the New Ireland art style. These relations between motifs permit individual patterns to be distinguishable and therefore recognisable, suggesting that the 'principle of least difference' is also a way to articulate minute differences between *kapkaps*, even when the *kapkap* patterns look almost identical. But this abstract principle also constrains the generation of style, which is evident in the uniformity of the *kapkap* patterns, so that the patterns appear the same. Thus, the system of style maintains that patterns are characterized by a convergence towards the 'principle of least difference' – that is the axes of coherence for the New Ireland pattern – regulating the display of pattern in New Ireland and ensuring that no innovation occurs.

So far I have discussed how the principle of least difference impacts on the generation of style, acting as a device to regulate the dynamic creation of *kapkaps*. This stylistic system – autonomous in respect of its ability to generate a complete corpus from the one part of itself – is only detectable as a system of relations between all the *kapkaps* that exist in the New Ireland region. Thus, one individual *kapkap* is not enough to derive the stylistic system here. Now the next step is to ask whether this abstract structuring system extends beyond the provision of style. Could this abstract system have any bearing on the system of structures that regulate and maintain order in the social domain?

Let us begin by considering the 'principle of least difference' from a cultural perspective. Nalik society places stress on social difference and this concern is driven by the need to maintain social distance between kin relations, which necessitates avoidance and spatial separation, or elements of respect. These rules are enforced so as to avoid possible situations which could shame a person by coming into contact with avoidance relations. Paradoxically at the same time, Naliks are also concerned with the binding elements of social relations, spectacularly foregrounded in performances at mortuary feasts when clans, linked through common social relations, participate in competitive exchange in acknowledgement of their inter-relatedness.

One specific relationship that captures this paradox is the brother–sister relation. The brother and sister are of the same clan and same mother, but spatial distance is maintained between them. Even though the sibling pair maintains distance from each other, a bond still exists between them both, exercised in the brother's protection of his sister's social wellbeing. In turn, the sister has to carefully manage her sexual relations by concealing them to avoid harming her brother's social identity. Thus, the relationship demonstrates the paradox through a concern for difference (through spatial separation) but at the same time, a concern to maintain close ties (through mutual respect and care for one another).

Concerns for homogeneity and difference are manifest in the way Naliks trace social relations. The complex nature of social relations means that knowledgeable men and women can trace common ancestors between each other. In order to do this, expert knowledge of clan histories is required so that in times of disputes, clans can be rewarded when apparently unrelated clansmen trace ties to the same apical ancestor in order to lay claim to land. The complex network of social relations also makes many Naliks uncertain of who exactly they are related to and this is especially true for younger adults, who are unaware of their relatives in other villages. At mortuary feasts, many younger Naliks try to trace their relations to clansmen and women, so as to avoid potential subversions of the avoidance and respect laws which could arise over meetings with persons closely related through marriage but were previously unknown to them and could thus potentially damage their social being.

The changing nature of social relations also means that person–person relations are constantly shifting in Nalik society. As persons get older, they acquire new affinal relations, which means that relationships are transformed from respect or joking relations to altogether avoidance. Hence as clan siblings marry, many males and females who may once have brought betelnut to the house are now strictly avoided. Sorcery is also a factor in the reasons for avoiding certain hamlets or persons. Naliks are suspicious of many persons, and so as to protect themselves from potential attacks, tend to avoid certain places. Moreover, *kapkaps* are implicated in this: they protect the wearer from impending threats of sorcery and because of the constant fluidity in social relations, these threats are constantly changing focus.

It seems plausible therefore that these abstract structuring principles that order the artefactual domain are lived out in Nalik everyday life as a concern for social difference. So how did this congruence arise? The dynamic generation of style is the result of a long series of initiatives that have developed historically, which have given rise to what we understand today to be New Ireland style. The process of carving each new *kapkap* is a product of a sequence of stylist decisions that New Ireland carvers take. These decisions that generate coherence and stability in New Ireland art style, are never enacted without the knowledge of their social outcome and the threats that transgression may bring to clan strength. Thus, the subtle differences in generating the *kapkap* pattern with the prominent uniformity show a concern to establish difference, but concurrently show a recognition of their relation to a background of sameness.

The abstract logic that generates the *kapkap* pattern is lived out in ritual performances, made visible in the spatial positions Naliks take up at mortuary feasts. Here, Nalik men and women follow circular and linear pathways as they compete in ceremonial exchanges, tracing out the image of the *kapkap* in the hamlet space as they lay down shell money and partake in feasting in remembrance of the dead. And it is exactly these performances that the elementary curriculum targets, a time when the *kapkap* is displayed, the drum is beaten and dancers move through the village space.

CONCLUSION

This quality of logic which is 'good to think', carries with it mathematical thought, making pattern an effective tool in the school classroom for learning mathematics. It thus demonstrates how active thought processes involved in the generation of the *kapkap* pattern, lived out in everyday and ritual performances are translated into material form. And it is this translation from mental to material form that mobilizes mathematical thinking and spatial reasoning – thus making the *kapkap* an object of learning.

The curriculum innovation appears to be just the beginning for utilizing arts and crafts as tools for the learning of mathematics in Papua New Guinea. As Kaleva (1995) points out, there is no reason why the new directive should not be extended to the secondary school curriculum to further facilitate learning. This would inevitably help alleviate concerns by distant education learners at the University of Papua New Guinea who complain that their poor performance in the mathematics core course is due to the absence of concrete associations to the mathematics learnt in their villages (cf. Kari, 1998).

The mathematical ideas invoked in *kapkap* patterns are just one example of the artefactual world that enhances the process of learning. Future research into the field of objects of learning could examine other material aspects of objects like colour, texture and smell which may activate thought, proving beneficial for cultures that stress a visual rather than a text-based form of knowledge.

Notes

1. Following Clements and Battista (1992), I include spatial reasoning in my definition of mathematical knowledge.

2. There are over 800 ethnolinguistic groups in PNG, making it the most culturally diverse country in the world.

3. The *Elementary Curriculum Statement* states 'from the known to the unknown' (Department of Education, Papua New Guinea, 1998a: 1).

4. Simpson (1996) describes how the repatriation of Native American artefacts has regenerated indigenous lives by unlocking memories, facilitating the rediscovery of performances.

5. The *Elementary Scope and Sequence* (Department of Education, Papua New Guinea, 1998c) lists the types of mathematical skills set out by the curriculum.
6. According to Kahneman (1973), circular objects incorporating patterns are highly attractive to the naked eye.
7. Wagner (1986) takes an alternative approach by arguing that it is culture that generates culture.

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◆ **GRAEME WERE** is an advanced doctoral candidate in the Department of Anthropology, University College London. He was awarded an ESRC scholarship and the Emslie Horniman Scholarship for Anthropological Research for work on, 'Pattern, Thought and the Construction of Knowledge: The Question of the *Kapkap* from New Ireland, Papua New Guinea'. He is currently employed as the Research Co-ordinator on the ESRC-funded project 'Clothing the Pacific'. *Address*: Department of Anthropology, University College London, Gower Street, London WC1E 6BT, UK. [email: g.were@ucl.ac.uk]