Weaving Mathematics and Culture: Mutual Interrogation as a Methodological Approach

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Abstract

This paper describes an adaptation of a methodology called ‘mutual interrogation’ to a study on Malay weaving. The interrogation was focussed on the weaving technique, framework construction and pattern formation. Mutual interrogation is a process of implementing a critical dialogue between two systems of knowledge. Using this approach, a three-cycle dialogue between several weavers and mathematicians was implemented, with the researcher playing the role of a mediator. The interactions between the concepts of the weavers and the conventions of the mathematicians have uncovered several interesting perspectives, which consequently dispute several critics of ethnomathematical research.

Introduction

Mutual interrogation is a methodological approach that was first proposed by Alangui in 2006 as a way of addressing some of the critiques with regard to investigations of mathematical elements in cultural practices and artifacts (see for example Ascher, 1991; Gerdes, 1999, 2009; Zaslavsky, 1979). The most pertinent criticism is the one posed by Vithal and Skovsmose (1997), who question whether the process of interpreting cultural practice via mathematical concepts and models to determine the underlying thinking abstractions, will lead to the invention of new mathematical structures that reorganise the reality of the practice. The authors are mainly concerned about the implications and consequences of these investigations on the cultural practitioners; even though their activities are interpreted as embedding mathematics, their views and opinions are not consulted nor considered. Rowlands and Carson (2000) on the other hand, argue that many cultural practices that can be described mathematically are not necessarily mathematical. Therefore, they question the possibility of abstracting the 'relevant' mathematical ideas, and whether the abstraction is pertinent to the actual mathematics of that culture. This perception was later changed, and the authors now admit the prospect of achieving "very high level of (mathematical) abstraction, complexity and eloquence" from the practice (Rowlands & Carson, 2002, p. 92).

Another point raised by Vithal and Skovsmose (1997) is on the lack of ethnomathematical studies that focus on the relation between culture and power. This is despite the fact that the notion of ethnomathematics revolves around culture, and that culture is a social and political construct. Their view echo those of Millroy's (1992), who provided compelling evidence of the occurrence of power relations among the group of South African carpenters in her study. In this context, power relations were entrenched in the apartheid system and observed through forms of discrimination displayed towards the members in the lowest level of employment, the indigenous African labourers.

This paper presents the findings of an ethnomathematical study on the cultural practice of food-cover or *tudung saji* weaving among the Malay weavers in Malaysia. These findings were obtained through an adaptation of a methodology called mutual interrogation, which is proposed as a way to counter such criticisms above. Apart from studying the embedded cultural knowledge, the weaving practice was also used to explore the efficacy of this approach, and facilitate its recognition into the field.

Mutual Interrogation, as Proposed by Alangui

Mutual interrogation is defined as “the process of setting up two systems of knowledge in parallel to each other in order to illuminate their similarities and differences, and explore the potential of enhancing and transforming each other” (Alangui, 2010, p. 86). The systems of knowledge refer to the knowledge embedded in cultural practice (ie. cultural knowledge) and conventional, mathematical knowledge. The emphasis is on mathematics, because ethnomathematics is about finding or uncovering different ways of knowing that are regarded as constituting mathematical elements. The interrogation that occurs between the two knowledge systems is carried out through the process of critical dialogue that takes place between the cultural practitioners and the mathematicians through the researcher.

Dickenson-Jones (2008) referred to the online version when she criticised the definition. Her argument is, if two knowledge systems were set up ‘in parallel’ to each other, then they would never intersect, and hence, it would be impossible for one knowledge system to have any influence on the other. This opinion reveals a misunderstanding of Alangui’s true intention. In one sense, the words ‘in parallel’ in the definition implies the notion of equality. Thus, the two systems of knowledge; cultural knowledge and conventional mathematics, are considered to be equally important in the research process, provided with equal opportunity to interrogate each other, and are given equal value in the final report. Moreover, the two systems are parallel and equally valid in their respective contexts. In another sense, parallelisms refer to the similarities and differences that are drawn between certain aspects of mathematics and the cultural practice, to show the appropriateness of the latter to interrogate conventional mathematical concepts and beliefs. This is because any transformation of mathematical ideas might occur only when the systems are interacting and interrogating each other *equally and critically*.

Unlike many other writers in the field, Alangui (2006) deliberately avoids using the term ‘mathematics’ or ‘mathematical’ when referring to the cultural knowledge being investigated. His avoidance stemmed from the fact that he does not want to restrict his perspectives on what mathematics is all about, which might cause him to focus only on aspects of the cultural practice or knowledge that resemble conventional mathematics. Instead, he adopts Barton's (1999a) notion of QRS system to describe the mathematical knowledge system that exists in any cultural group. The QRS system is a system of meanings that occur when a group of people attempt to manage quantities, form relationships and represent space within their own surroundings (Barton, 1999a, 1999b). In other words, the QRS system encompasses other forms of knowledge or ways of thinking that might not initially be recognised as mathematical. This approach of broadening the conception of mathematics counters the view assumed by Rowlands and Carson (2000), where they focus only on the conventional, Western mathematical concepts when questioning the embeddedness of mathematical ideas in cultural practice.

The main reason for the development of this methodology is to avoid the unintentional perpetration of 'ideological colonialism' and 'knowledge decontextualisation' in ethnomathematical research (Alangui, 2010). Ideological colonialism or colonisation is defined as "the imposition of concepts and structures of mathematics onto the knowledge embedded in cultural practice", and knowledge decontextualisation as "the taking of knowledge and practice out of their cultural context in order to highlight their 'inherent' mathematical value" (Alangui (2010), p 11). Alangui believes that to avoid these 'dual dangers', it is essential to have a critique and dialogue that involve constant interrogation and challenges of assumptions, perspectives and methods. Since mutual interrogation acknowledges the standpoint and expertise of both knowledge systems, the dialogue becomes a platform for the cultural practitioners to voice their views and opinions. This is one instance where mutual interrogation addresses the concern raised by Vithal and Skovsmose above.

The researcher, who is also an ethnomathematician, plays a crucial role in this approach. This is because it is through him or her that the interrogation process between the practitioners takes place. Apart from facilitating the dialogue, the researcher is also expected to critically reflect on his or her assumptions and beliefs about mathematics and explore alternative conceptions, which might lead him or her to experience perceptual shifts about mathematics. In this respect, the notion of mutual interrogation can be considered as occurring internally. The critical reflections that the researcher engages in, the series of self-questioning, and the dialogue that goes on between him or her (as a representative of the cultural practitioners) and the mathematicians, allows the researcher to interrogate his or her own conception about mathematics. On the other hand, the communication of the outcome of the dialogue and the researcher's perceptual experiences to the larger mathematical communities represents the external aspect of mutual interrogation.

Alangui (2010) maintains that the interactions that occur between Western mathematical knowledge and non-Western knowledge systems with diverse concepts and ways of thinking about quantity, relationship and space, would eventually lead to a broadening or transformation in conventional mathematical ideas. Furthermore, the transformation might lead to the invention of new mathematical structures, as well as contemporary development of the cultural practice.

Mutual Interrogation, as Conducted in the Study of *Tudung Saji* Weaving

This study was carried out with the aim of testing the efficacy of mutual interrogation and facilitating its employment as a methodology in ethnomathematical research. Thus, mutual interrogation was implemented at a deeper level in this study, where the dialogue between the weavers and the mathematicians occurred in three cycles of fieldwork that spanned over one-and-a-half years. This is to ensure that each party received ample opportunities to interrogate the other, and that matters of interest were sufficiently and satisfactorily discussed through repeated interactions. The dialogue was mediated by the researcher, and following Alangui's lead, ethnographic methods of data collection, such as participant-observation, audio and video recordings and field notes, were used extensively throughout the investigation. However, in the context of this study, the word 'dialogue' was interpreted as the spoken words and conversations that transpired between the practitioners in both fields, as opposed to between the two knowledge systems, as suggested by Alangui (2010). This is because it was the practitioners who provided insights into their respective knowledge systems, so the words and the language they used to convey their understanding of both their own and the other's practice were deemed important to the research.

The Malay *Tudung Saji*

These conical covers are woven using a specific technique called triaxial or hexagonal weave, where the strands are plaited in three directions. Used to be objects that were commonly found all over Malaysia and the surrounding region (Gibson-Hill, 1951), the *tudung saji* are nowadays made in only a few states of the country due to a dwindling number of weavers. The weaver begins her work by building a cone-shaped latticework, which functions as a framework. Five strands are plaited together to form a pentagonal opening. This is followed by interlacing another five strands at the vertices of the pentagon to form hexagonal openings. The process of adding five strands each time is repeated to enlarge the structure, which forms its conical shape as more strands are added. Starting from the edge of the cone, coloured strands are interlaced upward and across the openings on the framework to create patterns, resulting in a hexagonal tessellation that at times gives the illusion of three-dimensional cubes.

 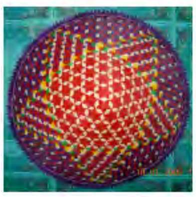   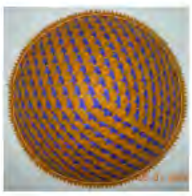

Figure 1: Several typical *tudung saji* patterns

The dialogue was started by showing these objects to the mathematicians to record their first impressions. The exchanges of ideas that took place between the weavers and the mathematicians with regard to the weaving technique, framework construction and pattern formation went on as follows.

Mathematical Observations

The mathematicians used words like ‘tessellated parallelograms’ and ‘repeating hexagons’ to describe what they saw, noting that some of the patterns appear neat and simple whereas others seem more complex and intricate. On the whole, the mathematicians were mostly interested in the formation of the patterns. They perceived the symmetry in the colorfully tessellated patterns, and the way the different coloured strands are repeated in each of the five sections in order to form the desired patterns or designs. They observed that many of the patterns, which are forced by the choice of colours, have five-fold symmetry at the top and six-fold symmetry everywhere else due to the way the strands are woven in the pentagonal and hexagonal openings of the framework.

Discontinuity in Certain Patterns

In Cycle 1, the mathematicians were curious about the discontinuity observed on some of the patterns, such as the last pattern displayed in Figure 1. Here, the parallel rows of ‘sailboats’ seen on half of the surface are disrupted near the top by a discontinuity line that splits the motifs in two directions. Consequently, this pattern loses the group of symmetry normally observed on the other patterns.

When this matter was discussed with the weavers in Cycle 2, they explained that the discontinuity is a natural occurrence that results from the interaction between the five-strand insertions at the peak (which consist of two different colours) and six-strand insertions on the body (five to six connections) of the cover. In addition, each stage of insertions encompasses three consecutive sections that curved around the framework. As the weaving proceeds from one insertion stage to the next, the strands on all five sections will eventually overlap in three directions. Hence, the combined action of arranging the strands at the peak and the interlacing of the strands to form the body of the cover determines the pattern that develops. In certain cases, the meeting between the strands that originate from the peak and those between two neighbouring sections gives rise to either discontinuities or deformities in the pattern. Some distortions can be corrected by covering them with extra strips, but others are too extensive to be corrected and are thus left alone.

Reconstruction of Framework

When it was mentioned that the weaving of the framework must be started with five strands in order to form a curvature at the pentagon and attain the conical shape, the mathematicians mulled this over and wondered whether it would be possible to build the framework with another number of strands. They accepted the weavers' claim that the structure would lie flat if the weaving was started with six strands, but they were curious and wanted to know what would happen if the framework was begun with three, four or seven strands.

Toward the end of Cycle 1, a conical-shaped, triaxially-woven latticework that was started with four strands was built based on the structural construction of old Chinese hats (Gibson-Hill, 1952). This structure was shown to the weavers in Cycle 2 and they were invited to reconstruct it and figure out possible ways of filling up the openings. Since they had always believed that the cone shape could only be obtained with a starting point of five strands, all of the weavers were quite surprised to see their weaving convention challenged. After several attempts, they succeeded in forming a peak of four strands, and proceeded to fill up the rest of the openings. However, due to its shape, which when compared to the regular

5-strand peak cover is sharper at the apex and narrower around the edge, the weavers unanimously decided that the new structure was unsuitable to be used as a *tudung saji*.

Two of the weavers later claimed that it is possible to make a three strand-peak, conical cover. However, the triaxial weave occurs only at the apex, and the succeeding weaving technique follows the rectangular mat weaving style, where the strands are interlaced perpendicularly to each other. In other words, this piece of work does not permit any openings and therefore requires no insertions. As a result, it allows no creation of the typical patterns. This style is unpopular with the weavers because it is much more difficult to make, time-consuming, and costly since it requires the use of many strands. Furthermore, only weavers who are skilled in the creation of the mat-weaving patterns can produce a cover of this type. All of these reasons render the production of this structure impractical and uneconomical.

Gerdes (1994) suggests that hidden mathematical ideas can be uncovered through a reconstruction of past knowledge. In order to understand the reasons behind the form of the product, it is necessary to learn the production techniques and vary the form at each stage of the process. This method is claimed to be helpful in observing the practicality of the product and the possibility of the form being the optimal or only solution of a production problem. This view is quite relevant to the above issue of *tudung saji* construction. Even though the conical shape could still be obtained by using three or four strands as the starting point, it appears that a starting point of five strands is the most favourable in ensuring the right proportion of the shape and size of the covers. Furthermore, it is easier to create patterns that are attractive and symmetrical on covers with five-stand peaks.

In Cycle 2, none of the weavers had tried constructing a cover by using seven strands as the starting point. They promised to give it a try and show the result in Cycle 3. The weavers expected that seven strands would be needed to fill up the tip, but since the opening would be considerably larger than usual, they did not think that the peak would be sharp. When this opinion was relayed to the mathematicians in Cycle 2, one of them asserted that it should be possible to build a seven strand peak cover. Basing his argument on concepts in hyperbolic geometry, he predicted that the formation would be saddle-shaped in appearance. He added that although the weavers might find the saddle shape of no use to them, it would still be an interesting finding from a mathematical point of view.

At the beginning of Cycle 3, the weavers were invited to separately weave a framework that was started with seven strands. The outcome was exactly as that predicted by the mathematician – the object lost its conical shape altogether and instead was transformed into something that was noticeably saddle-shaped in appearance. Furthermore, the shape became more pronounced after the proper insertions were made to close the openings. All of the weavers were quite indifferent to this object because it was considered not relevant to their weaving practice. The mathematicians on the other hand, showed significant interest in the transformed shape and the underlying mathematical properties that caused the transformation.

Extension to Weaving

The experiments that were conducted in Cycle 2 (where the weavers attempted to build frameworks that were started with four strands) led to an extension of constructive concepts in one of the weavers. She had successfully created two versions of *tudung saji* that consisted of two and three peaks, respectively. When shown to the other weavers, all of them liked the two-peak version, which was decidedly wider around the edge when compared to the regular single-peak, and therefore would be able to cover more dishes of food. On the other hand, the three-peak cover did not generate much interest among the weavers due to its shape, which was narrow and tall.

Figure 2: Two-peak (left) and three-peak (right) covers

A positive implication of this innovation is the potentiality of the two peak *tudung saji* being sold in the market. The same weaver had previously had some success in selling the high and narrow *tudung saji* that she built by interweaving only four strands at the starting point (i.e. the four strand peak cover). Despite the negative views that were adopted by the other weavers with regard to its odd-looking shape, she had found it an interesting invention and wanted to test its saleability. According to her, one of the buyers bought the *tudung saji* because of its height, which was considered useful for covering tall objects like tea sets. It was in fact the success of her sales that prompted her to think beyond her normal weaving scope, which subsequently led to the conception of the idea behind the creation of the two peak and three peak versions described above.

Weaving Template

At the end of Cycle 1, a computer-generated weaving template was developed to create triaxial plane patterns. Several fictitious patterns were created and shown to the weavers in Cycle 2 to seek their opinions on whether the patterns could occur naturally if woven on a framework. The general impression gained from this exercise was that all of the fictitious patterns could be created; it was just a matter of knowing whether they could occur naturally, or if there were parts that would require some covering up with other strands. Figure 3 displays a sample of these fictitious patterns.

Figure 3: A fictitious pattern

One weaver who was very excited when first told about the weaving template, showed some disappointment when she finally saw it. She had thought the template could help her in creating new patterns, something that she has always wanted to do. In her opinion, it was only good for producing patterns on a flat surface, and might not work for creating patterns on the three-dimensional framework. This is because the weaving structure on the template does not follow the weavers' convention, where three out of five sections of the cover are covered at each stage of weaving. She suggested that the template be modified to represent all 5 sections, instead of just one.

The weaver's comment was taken into account and efforts were made to modify the weaving template. With the help of a mathematician, diagrams that showed all five sections of the cover were created using the PSTricks package in LaTEX. The process of creating a common pattern revealed how the structure looked like if the peak consisted of seven strands (Figure 4). The wave-like appearance of the seven-strand peak is consistent with the saddle-shape formation that was predicted by the mathematician in the earlier section.

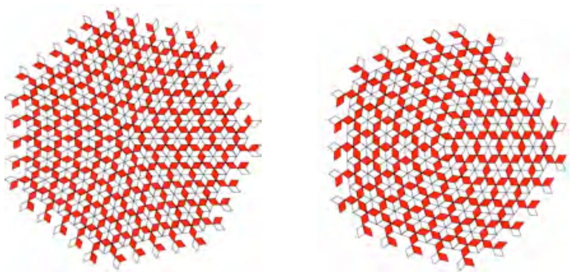

Figure 4: Diagrams of seven-strand peak (left) vs five-strand peak (right) structures

With regard to the perceived limitation of the weaving template, another mathematician commented that it is not necessary to create a template that exactly emulates the weaving convention of the weavers to show how the patterns are formed. His argument revolved around the fact that mathematicians are not interested in learning the know-how of *tudung saji* making, thus it is sufficient to display only a single section to represent the patterns. However, he had overlooked a crucial element in the process of *tudung saji* weaving, namely the framework construction. By pointing out why it would be almost impossible to determine the viability of pattern creation based on a single section, the weaver was in fact highlighting the importance of the framework in her practice. Her depth of knowledge of the practice had contributed in highlighting an aspect of weaving that would otherwise have gone unnoticed.

Conclusion

From the above findings, it appears that the interactions between the weavers and the mathematicians had succeeded in uncovering several perspectives that concerned both parties. This is evidenced by the innovative ideas developed by one of the weavers (e.g. the creation of two peak and three peak *tudung saji*) since participating in the dialogue with the mathematicians. To put it another way, the dialogue had helped in enhancing the constructive concepts and to a certain extent, changing the weaving perspectives of the *tudung saji* weavers. The mathematicians on the other hand, had gained some insights in food-cover weaving, a cultural practice that was previously unknown to them. They were quite fascinated by not only the aesthetic values of the objects, but also by the mathematical ideas that are embedded within the practice.

On the whole, the weavers and the mathematicians were both highly engaged in the dialogue, especially in the first two cycles. Nevertheless, the weavers did not quite ‘interrogate’ the mathematicians as much as they were being interrogated. Instead, they preferred to simply accommodate the wishes of the mathematicians by following their suggestions and answering the queries that were posed to them. This is especially apparent in the last two cycles, when the investigation was focussed more on uncovering the mathematical ideas behind the framework construction. A possible explanation for this 'imbalance' could be attributed to the difference in perspectives, an aspect that is normally dependent on the individuals' background and interest. The food covers evoked feelings of mathematical curiosity in the mathematicians, so they posed questions and made suggestions to make mathematical sense that satisfied their curiosity. On the other hand, the weavers generally did not have much of a mathematical background to begin with and therefore did not develop many insights into the abstract world of mathematics. As admitted by several of the weavers, mathematics is a subject area that is beyond their understanding. As a result, they did not know what questions should be posed to the mathematicians with regard to their weaving practice. Nevertheless, even though the weavers might not normally be looking at the things around them with a mathematical eye, they could see some form of mathematical elements in their weaving practice, citing the relationship between the techniques in pattern formation and the emerging patterns as an example.

Another possible explanation for the inequality in the interrogation is due to the existence of power relations between the practitioners. The weavers perceived the mathematicians as highly knowledgeable people and might have felt quite intimidated when they were brought together through the dialogue. The mathematicians on the other hand, were confident in their understanding of their knowledge system and therefore felt comfortable enough to interrogate the weavers. In this context, power relations existed even though the practitioners did not meet face-to-face. This is consistent with Vithal and Skovsmose's argument, who assert that cultural practice "is not only the result of interactions with the natural and social environment but also subjected to interactions with the power relations both *among* and *within* cultural groups" (Vithal & Skovsmose, 1997, p. 140).

So how effective is this methodology called mutual interrogation? The practitioners who take part in the dialogue could rest assured that their voices would be heard. They would also be provided with equal (and ample) opportunity to interrogate each other, to exchange ideas between members of the same group, and to enhance their understanding of the practice of the other group. There is evidence that the dialogue could contribute towards extending the practitioners' conceptions about their practice, as shown through the structural changes in framework construction. The interactions had also helped in drawing the weavers' attention to the ways of how mathematical theories could be used to enhance their weaving practice.

The mediator or researcher plays a major role in this approach. It is his or her responsibility to keep the dialogue going by reflecting on the things that has been said and done. Care must be taken here, because whatever that the researcher chooses to highlight to the other party would determine to a certain extent the way the dialogue is going. During the interactions and the communication of the outcome, the researcher must be open to ideas and opinions, and willing to allow his or her mathematical conceptions to be challenged. Then only a transformation in mathematical ideas could exist.

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