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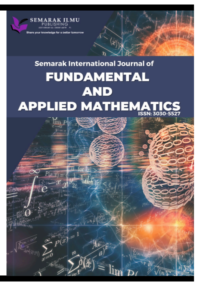


# Geometric Transformations in *Kelarai Cik Kedah Ketapang*: Exploring the Mathematical Foundation of a Traditional Malay Weaving Pattern

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**ABSTRACT**

*Kelarai Cik Kedah Ketapang* is a traditional handmade weaving pattern passed down through generations in Malay culture, originating from Terengganu, Malaysia. While its aesthetic and cultural significance has been widely acknowledged, its underlying mathematical properties remain under-explored. This study investigates the geometric transformations that contribute to the arrangement and design structure of the *Kelarai Cik Kedah Ketapang* pattern. Using geometric modelling and comparative visual analysis of archival and present samples, the study identifies isometric transformations, including reflections, translations, and rotations, as fundamental to the pattern's composition. Additionally, the integration of combined transformations and repeated geometric characteristics plays a crucial role in maintaining the motif's structural coherence and visual appeal. The findings highlight traditional weavers' intuitive application of mathematical concepts, demonstrating that mathematical thinking is deeply embedded in this Malaysian craft.

## 1. Introduction

*Kelarai* is the traditional art of hand-weaving in Malaysia. Dewan Bahasa dan Pustaka [1] defined *kelarai* as checkered weave patterns. Bakar *et al*. in [2] stated that *Kelarai* can be identified when multiple simple patterns are arranged to form a geometrical pattern. In addition, Ibrahim in [3] found that every *kelarai* woven pattern uniquely relates to the world's realm. Traditional weavers tended to implement nature elements as motifs for *kelarai* weave design, including flowers, plants, insects, animals, the cosmos, and the names of people as presented by Perbadanan Kemajuan Kraftangan Malaysia [4] and Ramiah [5] in Figure 1.

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**Fig. 1.** Examples of different types of *kelarai* motifs [5]

In 2023, Ismail *et al.,* [6] found that the *Kelarai* can be used in a wide variety of products, from everyday mats and food covers to decorative elements such as walls and windows of traditional architecture. It holds both cultural and mathematical significance. This art form is integral to cultural identity, economic development, and the preservation of traditional skills, highlighting the broader impact of preserving weaving arts beyond textile applications as stated by Hidayani [7].

Hj. Awang in 2007 [8] mentioned that *Kelarai Cik Kedah Ketapang* is one of the traditional *kelarai* patterns that originated from Ulu Marang, Terengganu, Malaysia, first produced on a mat. The element of the pattern is inspired by the name of a person, *Cik Kedah Ketapang*. Weaving is the process of intertwining or weaving sheets or strips of material into a strong and usable bundle by following certain disciplines. The procedure of making it follows a few steps which are searing, splitting, soaking, colouring, and weaving the leaves into desired forms as stated by Puteh *et al.* in [9] as in Figure 2 and Figure 3.

**Fig. 2.** Weaving of Mengkuang Mat [10]

**Fig. 3.** Process of weaving [11]

In addition, *Mengkuang* (Pandanus artocarpus) and *pandan* (screwpine) are usually preferred to produce *kelarai* woven products as both plants are readily available around them as research by Ahmad Zakaria *et al.* [12]. According to Idris *et al.* in [13], *kelarai* weaver entrepreneurs are mostly from the east coast states of Malaysia-Kelantan, Terengganu, and Pahang. Perbadanan Kemajuan Kraftangan Malaysia in [14] reported that Madam Hajah Kelsom Abdullah, known as Madam Ani, received the 2018 Adiguru Award for her contributions to Malaysia's weaving industry. She created opportunities for housewives and aspiring weavers, offering paths to income. Internationally, she taught mengkuang weaving in Germany in 2014 and attended Bangladesh's Asia Craft Seminar in 1989.

Ethnomathematics is defined as the study of the relationship between mathematics and culture. This means that the value of mathematics is supported by the science of mathematics itself and the culture of the society in which mathematics is taught and developed. Ismail *et al.*'s research in [15] explains that ethnomathematics connects culture and mathematics from various aspects, namely art, literature, religious education and thought. Ismail and Mohd Atan [16] stated that the application of this field of mathematics helps a lot to provide solutions in daily life, among which is the field of art. Mathematics is an art that includes geometric shapes that are processed and diversified to produce an attractive and perfect pattern. These studies conclude that mathematical ideas are culturally absorbed and embedded in the games, artifacts, music, and daily activities of all the cultures studied.

The framework of ethnomathematics, which links cultural practices with mathematical thought, provides valuable insight for analysing traditional arts like *Kelarai Cik Kedah Ketapang.* This perspective reveals the mathematical patterns embedded in these designs, aligning with studies on *Sarong Pelikat* patterns by Wan Bakar *et al.,* in [17], which emphasise the connection between mathematics and cultural arts. As Abd Rahim *et al.* in [18] argue, the mathematical thinking embedded within Malay cultural practices reflects the long-standing integration of cultural values and mathematical concepts. Despite this art's intricate design and cultural value, there is a gap in scholarly work examining its mathematical structure and the role of geometric transformations in its patterns. Addressing this gap is significant not only for preserving Malay heritage but also for advancing the field of ethnomathematics by providing insights into how traditional artisans apply mathematical principles intuitively. Thus, this study aims to analyse the application of geometrical characteristics in *Kelarai Cik Kedah Ketapang* motifs, contributing to a greater appreciation and understanding of the mathematical knowledge embedded in Malaysian traditional crafts.

## 2. Methodology

In this paper, mathematical concepts related to geometrical characteristics are viewed as integral to the cultural practice of *Kelarai* Cik Kedah Ketapang.

In 2017, Harlizius-Klück in [19] stated that weaving had been a binary art from its very beginning, applying operations of pattern algebra for millennia. Meanwhile, Bentley in [20] found that doing mathematics in weaving practice is inseparable from the physical activity of manipulating the threads. In 2022, Sousa Silva and César Pinheiro [21] indicated the presence of counting elements, operations, symmetry and plane geometry and specific characteristics associated with the dimensions of the Ethnomathematics Program. In 2014, Zamri *et al*. in [22] proved that the *Tudung Saji* weaving is relevant to the study of group theory. They found that every element in the specific *tudung saji* patterns can be mapped to some of the elements of the finite group.

In 2017, Hj. Baharam *et al*., in [23] explain that transformation is the process of changing the direction, orientation or size of an object's image through translation, reflection and rotation. The transformation process involves an object and an image. An object is the initial position of a pattern before undergoing a transformation process, which frequently denoted as an alphabet (X) while an image is the final position of a pattern after undergoing a transformation process, which also frequently denoted as (X'). Isometric transformation is a geometric transformation that preserves distances between points, meaning the size, shape, and angles of an image remain unchanged and congruent after the transformation process. Translation is the transfer of all points on a plane in the same direction and through the same distance. Reflection is a transformation that occurs when all the points on the plane are reversed in the same plane on a line. The line is called the axis of reflection. Rotation happens when all points of an object are rotated from a centre of rotation depends on angle and the direction of the rotation. Some isometry operations on transformation are shown in Table 1.

**Table 1**
Isometry operations and their conforming elements

| Isometry operation | Geometrical representation | Isometry element |
|---|---|---|
| Translation | Vector | Translation vector |
| Reflection | Line (axis) | Axis of reflection |
| Rotation | Point (centre) | Rotation centre |

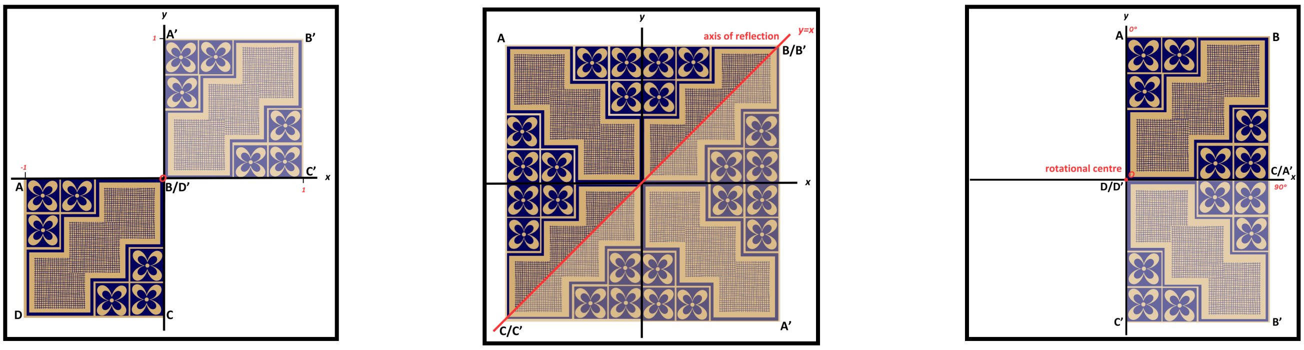
This study exclusively focuses on ***Kelarai Cik Kedah Ketapang***, as it is well-suited for **geometrical analysis** due to its **structured and repetitive motifs**. The research examines the **transformational properties** of this pattern, including **translation, rotation, and reflection,** without extending the analysis to other *Kelarai* patterns. While the findings provide valuable insights into the mathematical properties of ***Kelarai Cik Kedah Ketapang***, they **cannot be generalised** to other *Kelarai* patterns without further research. The ***Kelarai Cik Kedah Ketapang*** pattern was first sourced from online references and then digitally reconstructed using **Canva.** Through manual identification, the pattern was determined to have a **square-based repeating unit**, which can be divided into **four isometric quadrants.** Each quadrant consists of **six floral motifs**, separated by **three squares overlapping at their corners**. As a result, the **basic unit** comprises **24 floral motifs and 12 squares**, forming a **cross-like symmetry** at its centre.

To move beyond literature summaries, this study engages **group theory** to mathematically classify the **symmetry properties** of the pattern. The basic unit of the *Kelarai Cik Kedah Ketapang* pattern exhibits **four axes of symmetry**, **four vertices**, and **four 90° interior angles**, making it a strong candidate for **dihedral symmetry (D4)**.

The following **isometric transformations** were applied systematically:

- **Translation** – Repeating the basic unit across a plane while preserving its structure.
- **Rotation** – Rotating the basic unit by **90°, 180°, and 270°** around a central point.
- **Reflection** – Flipping the pattern across vertical, horizontal, and diagonal axes.

By analysing these transformations, it is possible to categorise the pattern within the **wallpaper group classification** and determine its **mathematical properties** in woven design. Figure 4 provides visual representations of these transformations, illustrating how the pattern maintains symmetry under different group operations. This approach not only ensures a rigorous mathematical understanding of *Kelarai Cik Kedah Ketapang* but also bridges the gap between **traditional woven art and modern symmetry analysis**. Future studies can incorporate **computational modelling** to automate symmetry classification, further enhancing the mathematical framework for Malaysian woven patterns.




Translation $\begin{pmatrix}1\\1\end{pmatrix}$ | Reflection at line y=x | Rotation 90°Clockwise at the origin point

**Fig. 4.** Visual presentation of transformation

Combined transformation is a combination of two or more transformations. For example, transformations P, transformation Q, and transformation S combine to form transformation PQS, but the order of application is reversed, transformation S is followed by transformation Q, followed by transformation P. Meanwhile, Pearce in [24] and Third Space Learning in [25] stated that reflecting a triangle across the *x*-axis and then rotating it 180° about the origin can result in the same orientation as a single reflection across the *y*-axis. This demonstrates how combined transformations sometimes simplify to a single equivalent transformation, showcasing the interrelationships between different geometric operations. In addition, Pearce in [24] mentioned that the sequence in which transformations are applied can change the outcome. For example, translating a shape and then rotating it often yields a different result than rotating first and translating afterwards. This emphasises the importance of understanding the order when working with combined transformations.

In 2022, Subani *et al.,* in [26] conducted research on the concept of transformation in Pandan Mat weaving art. Weavers across the United States and Canada identified three instantiations of mathematics that emerged through their making processes: arithmetic and calculations, image and shape transformations and multiple embedded patterns as stated by Thompson in [27]. Mathematical Institute SANU in [28] collected that the use of geometric transformations, including translations, rotations, and reflections, in the crochet and weaving arts was investigated by Del Mar and Timbol. The authors talk about how symmetry groups, which incorporate these transformations, help textile artists produce designs that are both aesthetically pleasing and structured. This link emphasises how mathematical changes are essential to weaving as an artistic medium. In the explanation of the application of rotational symmetry to weaving, Seitz in [29] offers a real-world illustration of how the ideas of rotation and reflection can be combined to produce aesthetically pleasing and harmonious woven patterns. These changes, particularly rotation and translation, aid in weaving by preserving consistency and producing complex repeating designs.

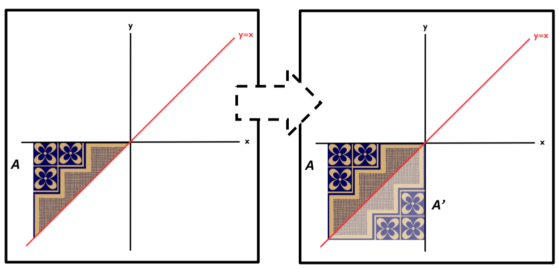
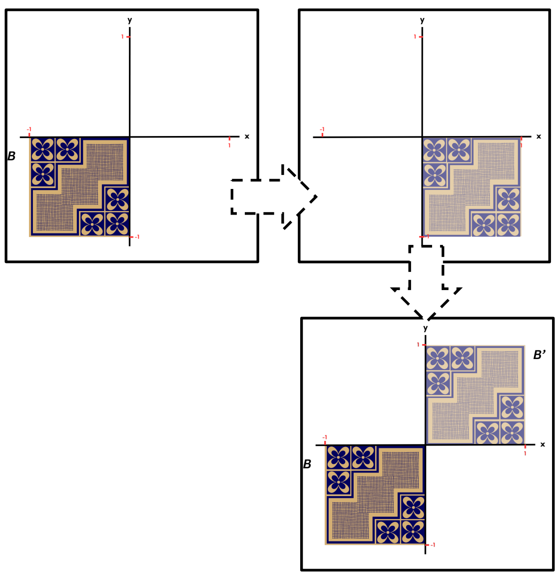
Based on the previous study of patterns using geometry and algebra, this research is done by analysing the arrangement and pattern of *Kelarai* Cik Kedah Ketapang by using the three types of isometric transformation which are translation, reflection, rotation with the possible combined transformations and others geometrical characteristics.

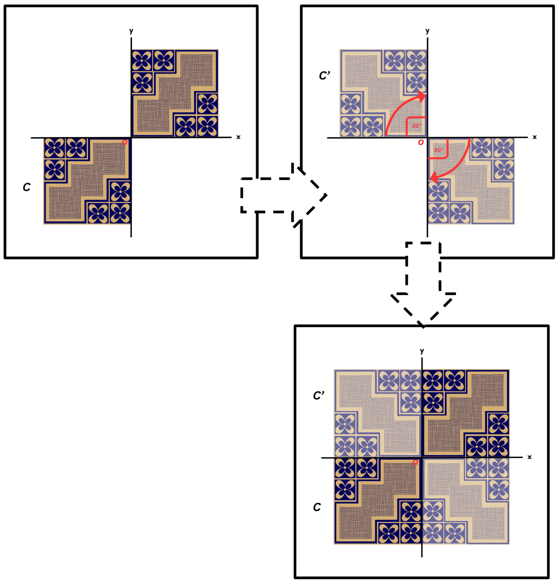
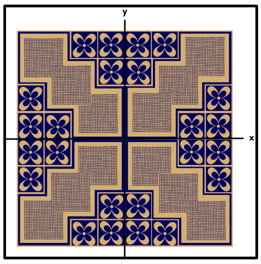
## 3. Results

In this section, the analysis of the *Kelarai Cik Kedah Ketapang* pattern using geometric transformations is presented. The analysis follows the arrangement of motifs and their transformation properties, which reveal the presence of isometric transformations, combined transformations, and other geometric characteristics of the pattern.

To examine the geometric characteristics, a Cartesian plane was constructed by identifying the *x*-axis, *y*- axis, and the origin point. A fundamental motif (referred to as template A) was selected from the pattern for analysis. The pattern's structure was then examined through a geometric modeling approach, applying reflection, translation, and rotation transformations. The results are summarized in Table 2, which provides a step-by-step analysis of how each transformation occurs within the pattern.

**Table 2**
Analysis of the patterns of *Kelarai Cik Kedah Ketapang*

| Templates | Characteristics |
| --- | --- |
|  | i. Triangle A is seen to undergo the reflection on the line $y = x$ to form an image denoted by A'.<br>ii. A' is the same shape and same size as A.<br>iii. A' has a different orientation, with inverted sides, creating a mirror image of A.<br>iv. Reflection is denoted as transformation S. |
|  | i. Triangle A and A' then combine to form square B, which is the new object.<br>ii. Square B is seen to undergo the translation $\begin{pmatrix}1\\1\end{pmatrix}$ to form B' which is the new image.<br>iii. Square B moves 1 unit to the right and 1 unit upward.<br>iv. All vertices transferred on a plane in the same direction and through the same distance.<br>v. B' is the same shape, size and orientation as B.<br>vi. Translation is denoted as transformation Q. |

| | |
|---|---|
|  | i. Square B and B' then combine to form shape C which is the new object.<br>ii. Shape C is seen to undergo a clockwise rotation of 90° at the origin point to form C'.<br>iii. C' has the same shape, size and orientation as C.<br>iv. The origin point also known as the centre of rotation is a stationary point.<br>v. The distance from each vertex on C' to the centre of rotation is the same as the distance from the corresponding vertex on C to the centre of rotation.<br>vi. Rotation is denoted as transformation P. |
|  | i. The shape C and C' are combined to form the *Kelarai Cik Kedah Ketapang* pattern.<br>ii. *Kelarai Cik Kedah Ketapang* arrangement and pattern are seen to undergo multiple transformations, resulting in an image that reflects all the transformations applied which are also known as combined transformations PQS.<br>iii. The arrangement and pattern of the *Kelarai Cik Kedah Ketapang* design appears to undergo a repeating pattern of shapes that covers a plane completely without any gaps or overlaps. |

From the analysis in Table 2, The ***Kelarai Cik Kedah Ketapang*** pattern is generated through a combination of **isometric transformations** applied in the sequence of transformation **S (reflection at line *y=x*), transformation Q (translation $\begin{pmatrix}1\\1\end{pmatrix}$), and transformation P (rotation 90° clockwise at the origin point).** The process begins with reflection along the central axis. Next, **translation** is applied horizontally and vertically. Finally, **rotation** is performed, typically by 90 degrees. The arrangement and pattern of *Kelarai Cik Kedah Ketapang* possess the geometry concept with the characteristics of reflection, translation, rotation, combined transformations and repetition.

The transformation sequence in traditional Malay weaving techniques demonstrates an intuitive application of reflection, translation, and rotation to maintain symmetry and structure. Historical woven patterns also reveal repetitive geometric structures, reinforcing the mathematical foundation behind the art. Studies on Islamic geometric patterns and Malay textile designs suggest that such transformations are integral to traditional craftsmanship, confirming the significance of geometric principles in heritage art.

Further supporting this connection, Ramli *et al.* in [30] explored the mathematical representation of Malay woven patterns by transforming *tudung saji* motifs into finite zero-one matrices using image processing techniques. Similarly, Ismail in [31] highlighted the use of geometric transformations in Malay traditional crafts, particularly in *songket* weaving and woodcarving. Research on Islamic geometric patterns, such as those by Abas *et al.* in [32] and Critchlow in [33], further emphasizes the inherent use of symmetry and repetition in traditional design.

## 4. Conclusions

This study demonstrates that *Kelarai Cik Kedah Ketapang* weaving art is deeply connected to geometric principles, particularly isometric transformations such as translation, reflection, and rotation. The analysis confirms that the arrangement of patterns preserves distance between vertices, size, shape, and angles—fundamental properties of isometric transformations. Furthermore, the design process involves combined transformations, which not only contribute to the complexity and distinctiveness of the pattern but also reflect the systematic mathematical reasoning embedded in traditional craftsmanship.

Beyond its mathematical significance, these findings have broader implications in the fields of ethnomathematics, design, and cultural heritage conservation. Understanding the geometric foundations of traditional weaving can aid in preserving and reinterpreting cultural artifacts, ensuring that indigenous knowledge remains relevant in modern design practices. Additionally, incorporating these mathematical principles into education can offer a more engaging and culturally enriched approach to teaching geometry, fostering appreciation for local heritage.

Moreover, the findings can be applied in digital recreations of traditional patterns, enabling the preservation and adaptation of these designs in modern applications such as digital art, textile manufacturing, and architectural ornamentation. By leveraging computational tools, the geometric structures identified in this research can be modeled and reproduced with greater precision, ensuring their continued relevance in contemporary creative industries. Future research could explore how these transformations evolve across different weaving traditions and their potential applications in contemporary design strategies, educational materials, and digital simulations.

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## References

[1] 4th ed. Kuala Lumpur: Dewan Bahasa dan Pustaka, 2005. Accessed [November 11, 2024]. https://prpm.dbp.gov.my/Cari1?keyword=*kelarai*&d=41812&.

[2] Bakar, Wan Norliza Wan, Rahaidah Muhammad, Rozita Shamsuddin, Raja Norazila Raja Mohd Yusof, and Syahirah Afiqah Mohd Taufik. "Kelantan Geometrical Designs on Malay Mengkuang Weaving Motifs." *Advanced Science Letters* 23, no. 8 (2017): 7915-7918. https://doi.org/10.1166/asl.2017.9608

[3] IBRAHIM, ISMAIL. "Hubungan motif dan ikon alam dalam pembentukan corak anyaman murut dalam konteks rekaan kontemporari." *International Journal of Creative Future and Heritage (TENIAT)* 1, no. 1 (2013): 129-165. https://doi.org/10.47252/teniat.v1i1.75

[4] Perbadanan Kemajuan Kraftangan Malaysia. *Serian Kelarai*. Kuala Lumpur: Perbadanan Kemajuan Kraftangan Malaysia, 1980.

[5] Ramiah, K. K. 2011. "Motif Anyaman *Kelarai*." Anyaman (blog). Blogspot. December 8. https://anyamankala.blogspot.com/2011/12/motif-anyaman-*kelarai*.html

[6] Ismail, N. H., Kiyai@Keai, G. A., Mustaffa Halabi, K. N., Abd Hamid, M., Harun, H,. Ramli, Z., and Abd Manan, H. "Mengkuang and pandan: The beauty of *kelarai* plaiting in Terengganu." *International Journal of the Malay World and Civilisation*, no. 3 (2023): 31-47. https://ejournals.ukm.my/jatma/article/view/74597

[7] Hidayani, Nieta. "Cultural heritage preservation: The art of traditional weaving is applied not only in clothing." *Jurnal Impresi Indonesia* 3, no. 2 (2024): 128-138. https://doi.org/10.58344/jii.v3i2.4636

[8] Hj. Awang, A. "Anyaman Mengkuang". PowerPoint presented at SMP Open University Malaysia, September 2007. https://www.scribd.com/doc/26415027/Anyaman-Mengkuang-Tikar.

[9] Puteh, Marzita, Sadiah Baharom, and Jamilah Omar. "Pemikiran Saintifik dan Matematik dalam Kraf Anyaman Buluh Melayu Tradisional: Satu Kajian Kes." *Jurnal Peradaban Melayu* 5 (2007). http://jurnalperadabanipm.blogspot.com/2008/08/pemikiran-saintifik-dan-matematik-dalam.html.

[10] BERNAMA. 2021. "Tikar Mengkuang Munah Masih Jadi Pilihan Selepas 30 Tahun." *BERNAMA*, 2021. https://www.bernama.com/bm/news.php?id=1931307
[11] SULONG, TOREK. 2020. "Seni Anyaman Tikar Tiada Pewaris." *Utusan Malaysia*, November 13, 2020. https://www.utusan.com.my/nasional/2020/11/seni-anyaman-tikar-tiada-pewaris/
[12] Ahmad Zakaria, R. M., Abdul Wahab, M. R., Abdul Samad, M. A., and Mat Yacob, S. N. "An analysis of symmetry in *kelarai* woven mat patterns in the Malay world." Jurnal Arkeologi Malaysia, no. 1 (2018): 19-26. https://arkeologimalaysia.org.my/jurnalarkeologi/index.php/jurnalarkeologi/article/view/179
[13] Idris, Mariam, Marzuki Ibrahim, Ruwaidy Mat Rasul, Mohd Noorulfakhri Yaacob, and Noris Fatilla Ismail. "Innovatively Preserving the Kelarai Weave Pattern Design through Photographic Documentation." *International Journal of Business and Technology Management* 5, no. S5 (2023): 395-406. https://doi.org/10.55057/ijbtm.2023.5.S5.43.
[14] Perbadanan Kemajuan Kraftangan Malaysia. "Adiguru Kraf Anyaman Pandan/Mengkuang Hajah Kelsom binti Abdullah." Laman Web Rasmi Perbadanan Kemajuan Kraftangan Malaysia. Last accessed November 11, 2024. https://kraftangan.gov.my/info/adiguru-kraf/hajah-kelsom-binti-abdullah.
[15] Ismail, Mat Rofa, and Ahmad Fauzi Mohd Ayub. "Seni Warisan Melayu: Satu Manifestasi Etnomatematik." *Institut Penyelidikan Matematik, Universiti Putra Malaysia*, (2012): 29-45. http://psasir.upm.edu.my/id/eprint/26441
[16] Ismail, Mat Rofa, and Kamel Ariffin Mohd Atan. "Mathematics in the Malay world Prior to the Arrival of Western Mathematics." *Procedia-Social and Behavioral Sciences* 8 (2010): 729-734. https://doi.org/10.1016/j.sbspro.2010.12.101.
[17] Bakar, Wan Norliza Wan, Junaidi Awang, Nani Hartina Ahmad, Mohd Saipuddin Mohd Hasbullah, and Mohd Zafian Mohd Zawawi. "Sarong Pelikat Pattern in Contemporary Batik Design: An Ethnomathematics Study." *Jurnal Penyelidikan Sains Sosial* 4, no. 13 (2021): 142-151. www.jossr.com.
[18] Sulaiman, Rushana, M. Redhuan, and Halim Husain. "Symmetrical design analysis of malay arts in ethnomathematics context." *Sciences* 10, no. 9 (2020): 1047-1060. http://dx.doi.org/10.6007/IJARBSS/v10-i9/7984
[19] Harlizius-Klück, Ellen. "Weaving as binary art and the algebra of patterns." *Textile* 15, no. 2 (2017): 176-197. https://doi.org/10.1080/14759756.2017.1298239
[20] Bentley, P. "Weaving Is a Way of Doing Math." I*n Proceedings of Bridges 2023: Mathematics, Art, Music, Architecture, Culture*, 361–364. 2023. https://archive.bridgesmathart.org/2023/bridges2023-361.pdf.
[21] de Sousa Silva, Cleisiane, and Paulo César Pinheiro. "The mathematics of geometric drawings in the Resende Costa's Handicraft Weaving." https://doi.org/10.20396/zet.v30i00.8660970.
[22] Zamri, Siti Norziahidayu Amzee, Nor Haniza Sarmin, Noor Aishikin Adam, and Atikah Mohd Sani. "Modelling of tudung saji weaving using elements in group theory." *Jurnal Teknologi (Sciences & Engineering)* 70, no. 5 (2014).https://doi.org/10.11113/jt.v70.3516.
[23] Hj. Baharam, B., Hj. Baharam, B., Ahmad, N. J., Mohd Tahir, J., and Mohd Hanafiah, M. N. *Text Book Mahematics Form 2 KSSM*. Kuala Lumpur: Rimbunan Ilmu, 2017.
[24] Pearce, D. 2022. "Exploring Symmetry and Transformations." *Math Insights* (blog). Math Insights Publishing. March 15. https://mathinsights.com.
[25] Third Space Learning. 2023. "Understanding Transformations: Reflections and Rotations in Geometry." *Third Space Learning Blog* (blog). Third Space Learning. January 10. https://thirdspacelearning.com.
[26] Subani, N., Mohd Abdullah, U. H., and Zulfikri, F. B. "The concept of transformation on pandan mat weaving art." E-*Proceedings of the 3rd Insan Junior Researchers International Conference 2022 (iJURECON 2022),* (2023): 73-77. https://oarep.usim.edu.my/handle/123456789/16459
[27] Thompson, Naomi. "Weaving in: Shifts in youth mathematical engagement through weaving." *Educational technology research and development* 72, no. 1 (2024): 15-39. https://doi.org/10.1007/s11423-023-10316-y.
[28] Mathematical Institute SANU. "Isometric Transformations and Symmetry Groups." Visual Mathematics Archive. Accessed November 16, 2024. https://www.mi.sanu.ac.rs/vismath/jadrbookhtml/part03.html.
[29] Seitz, J. "Rotational Symmetry in Weaving." Art with Mrs. Seitz, 2019. https://artwithmrsseitz.blogspot.com/2017/05/rotational-symmetry-weaving.html.
[30] Ramli, Masnira, Muhammad Azrin Ahmad, and Mohd Sham Mohamad. "Zero-One Matrix on Tudung Saji Pattern via Image Processing." https://doi.org/10.37934/araset.44.2.89101
[31] Said, Ismail. "Visual composition of Malay woodcarvings in vernacular houses of Peninsular Malaysia." *Jurnal Teknologi (Sciences & Engineering)* (2002): 43â-52. https://doi.org/10.11113/jt.v37.527.
[32] Abas, S. J., Salman, A., M. A., and Atiyah M. *Symmetries of Islamic Geometrical Patterns*. Singapore: World Scientific Publishing, 1994. https://doi.org/10.1142/2301
[33] Critchlow, K. *Islamic Patterns: An Analytical and Cosmological Approach.* London: Thames & Hudson. 1983.