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Ethno-Science, Technology, Engineering, and Mathematics (EthnoSTEM) Ideas in the Sama Mat-Weaving

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Abstract

Mat weaving has been culturally and economically significant among the Sama ethnolinguistic group since time immemorial. This study sought to find concepts and processes of ethnoscience, ethnotechnology, ethnoengineering, and ethnomathematics (ethnoSTEM) present in weaving *tepo*, a hand-woven mat of the Sama, made from indigenously processed leaves of *pandan* or screw pine *(Pandanus tectorius)*. To determine ethnoSTEM ideas, concepts, and processes in *tepo* weaving, an ethnography was conducted involving five female mat weavers in a coastal village in Tawi-Tawi's major producer of *tepo*, the Municipality of Tandubas. Data were gathered primarily through observations during a monthlong community immersion. Results revealed that Ethnotechnology tools were in the form of bolo, *pandan*-presser, *pandan* slitter, traditional stove, bamboo scalp scratcher, and other local cooking tools, with each tool exhibiting unique characteristics and functions needed for weaving. Ethnoengineering was evident in preparing *pandan* strips to create, bleach, and dye *pandan* strips for weaving and fastening the *tepo*. Ethnomathematics comprised primitive length measurement, arithmetic calculations, ratio and proportion, linear and quadratic equations, sinusoidal functions, basic geometric concepts, circles, symmetries, and isometries. Ethnoscience was observed in the processes determining the dyeability of *pandan* strips, as well as in the procedures employed in its softening and bleaching. It is concluded that the concepts and ideas of ethnoSTEM found in Sama weaving of *tepo* are loaded with scientific affluence that should be preserved to preclude them from fading to oblivion.

Keywords: ethnoscience, ethnomathematics, ethnoSTEM, ethnography, mat weaving

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The term "ethnomathematics" is attributed to Brazilian Professor Ubiratan D' Ambrosio, who studied the cultural aspects of mathematics in the late 20th century (Fouze & Amit, 2017; Rosa et al., 2016). D'Ambrosio (2016) recalled a 1976 critical discussion of Western-centric mathematics education, which focused mainly on transmitting mathematical content, with less attention given to social justice and cultural issues. This has paved the way to a new view on the history and philosophy of mathematics and their pedagogical implications— the Ethnomathematics. The latter is adapted in the present study as one of the four intertwined domains of ethnoSTEM along with ethnoscience, ethnotechnology, and ethnoengineering.

According to Rosa et al. (2016), D'Ambrosio explained that ethnomathematics presents the mathematics curriculum in a way embedded in students' cultural backgrounds and knowledge production. The notion then extended to how various cultural groups mathematize their daily activities and social, cultural, environmental, political, and economic context. D'Ambrosio (2016) emphasized that ethnomathematics is also applicable even in urbanized areas where traditional practices for common needs rely on what specialized workers, artisans, and trained professionals do in their daily activities. Hence, ethnomathematics is not restricted to the mathematical knowledge of the culturally distinct or indigenous group of people; rather, it also encompasses various human aspects such as social, historical, political, and economic, as Pais (2011) argued. These notions of ethnomathematics serve as the defining scope of ethnoSTEM that covers not only cultural but also all other peculiar aspects or strata of people in a particular context.

On the other end, Fasasi (2017) explained that ethnoscience uses the cultural beliefs and ideas of learners that relate to science concepts being taught and learned. It allows learners to give their fair share in building and processing the science concepts to be learned. As an integral domain of ethnoSTEM, this view of ethnoscience is used in the study in the context of Sama mat weaving.

In the light of ethnomathematics and ethnoscience, the term "ethnoSTEM" transpires. It should be noted that the prefix "ethno" is much broader than ethnic. D'Ambrosio (2016) demystified its connotation to mean a culturally identified group sharing similar knowledge and practices. From this, ethnoSTEM draws its perspective of STEM from the lens of a distinct cultural group of people sharing common knowledge systems, techniques, language, skills, values, and context across time and space. Hess and Strobel (2013) used the term "ethno-engineering" to describe indigenous engineering practices and principles from a literature review of 89 relevant sources. Notwithstanding, ethnoSTEM covers not only indigenous people but also those who belong to distinct cultural strata, such as working professionals, females, youth, amateurs, and the like.

Meanwhile, the works done by the Ethnomathematics Institute in Hawai'i demonstrated ethnoscience, ethnomathematics, and traditional technology. The latter is referred to in this present study as ethnotechnology. The institute explores issues of equitable and quality education through culturally responsive pedagogy in Pacific islands by forging partnerships with key stakeholders to support teachers' professional development. A collaborative curriculum design grounded on ethnic, historical, and cultural diversities of island communities is adapted to aid teachers in implementing culturally responsive mathematics pedagogy and connecting classroom curriculum to real-world application (Furuto, 2014). Similarly, this present study deals with the culturally responsive approach in Science, Technology, Engineering, and Mathematics (STEM), connecting the mainstream educational landscape with the Cultural Knowledge Systems and Practices (CKSPs) of the Sama cultural group in the island province of Tawi-Tawi, Philippines.

Mat Weaving of the Sama

The Sama people mainly live in the Southern half of the Sulu archipelago in the Philippines and many parts of the insular Southeast Asia (Ingilan & Jubilado, 2021; Gorlinski, 2016). Popular among those from the island province of Tawi-Tawi is the *tepo*, a hand-woven sleeping mat made from indigenously processed leaves of screw pine (Gorlinski, 2016). This mat is also used in their significant traditional occasions like weddings, thanksgiving, death ceremonies, aqeeqah, or Islamic tradition of animal sacrifice (i.e., slaughtering a goat or cow) on the birth of a child, and many more. Because of the stunning, vibrant, and complex design of the *tepo*, some people used it as decorative ornaments on the wall. *Tepo* products were locally sold for about 20 USD to 80 USD each, depending on the size, number of colors used, and complexity of design. Some of these were also sold even in urban places.

Pag-*tepo*, or mat weaving, has been a culturally significant and female-oriented activity among the Sama ethnolinguistic group in Tawi-Tawi since time immemorial. As the major producer of *tepo*, the municipality of Tandubas is known as the *tepo* capital of Tawi-Tawi. Among the main cultural landmarks of Tandubas were the large wooden pressers of *pandan* strips built in most of its villages, especially those in Ungus Matata. According to Tobias (2006), a master *tepo* weaver of Ungus Matata named Hja Amina Appi was given the Gawad Manlilikha ng Bayan or National Living Treasures Award in 2004 by the NCCA. Mat weaving is truly both economically and culturally significant among the Sama in Tawi-Tawi. This present research discusses some concepts and ideas of ethnoscience, ethnotechnology, ethnoengineering, and ethnomathematics in Sama mat weaving in Tawi-Tawi.

Materials and Methods

A case-focused ethnography was utilized to determine ethnoscience, ethnotechnology, ethnoengineering, and ethnomathematics in the mat weaving of the Sama ethnolinguistic group. The cultural sharing group consists of the Sama mat weavers as the sampling frame in Tawi-Tawi, the southernmost province of the Philippines. Mat weaving was the cultural theme of the ethnography. Five female mat weavers in coastal villages in the Municipality of Tandubas in Tawi-Tawi were observed doing mat weaving in December 2020. The mat weavers had 20 to over 40 years of experience at the time of the ethnography. Study sites and participants of the ethnography were accessed in the town of Tandubas, Tawi-Tawi. The local chieftains of the three villages in the said town served as gatekeepers of the study site. Permission and consent from the chieftains and the participants were obtained.

The ethnographic fieldwork employed a reflexive inquiry style in collecting extensive data through participant and non-participant observations. These data collection techniques are projected to generate ethnoSTEM domains found in mat weaving of the Sama ethnolinguistic group. During ethnography, a researcher puts himself in the context and collects data or participates with others in data collection (Willis et al., 2007). Thus, a month-long immersion period to experience mat weaving in the field was done in December 2020. Five mat weavers were observed doing their activities with the aid of self-designed fieldwork observation guides. A smartphone was used as a backup to record video footage of actual mat weaving.

Data from the observation field notes, photographs, and video recordings were organized and analyzed qualitatively to examine the ethnoscience, ethnotechnology, ethnoengineering, and ethnomathematics in mat weaving.

Results and Discussion

This section narrates, describes, and explains the ethnoSTEM concepts and ideas found in weaving *tepo*, a hand-woven mat of the Sama ethnolinguistic group made from indigenously processed leaves of *pandan*. These concepts emerged from the ethnography conducted in Tawi-Tawi's major producer of *tepo*, the Municipality of Tandubas. The findings are presented in this order: (1) Ethnotechnology or local and traditional technology tools used; (2) Ethnoengineering or the procedure and classical engineering design and processes involved; (3) Ethnomathematics, which presents mathematics in a way embedded in the activity; and (4) Ethnoscience or cultural beliefs and ideas that relate to science concepts.

Ethnotechnology in Mat Weaving

Twelve local tools in mat weaving discussed below are (1) bolo, (2) knife, (3) cooking pot, (4) traditional stove, (5) weight, (6) *pandan* slitter, (7) *pandan* presser, (8) bucket, (9) bamboo head-scratcher, (10) cooking pan, (11) needle, and (12) nylon string. Mat weavers in the community utilized relatively the same local tools in producing their *tepo*. This illustrated uniformity in using the tools from gathering the raw *pandan* to sewing the woven front *tepo* into its underlying woven rear *tepo*.

Bolo. The long single-edged and wooden handled bolo or *barih* in Figure 1.a was used by a mat weaver to cut mature leaves of the screw pine or *pandan* from its main trunk in the wild.

Figure 1.a

Local Tools used in Sama Mat Weaving: Bolo or Barih to Cut Pandan Leaves from the Main Plant (Photo taken by the Author in Tandubas, Tawi-Tawi in December 2020)

This 1-ft long and heavy tool in Figure 1.a could be used to slice a *pandan* leaf and remove its saw-like spines in the absence of a knife. It was locally available in the market at an affordable price. This was used not only in the forest or the sea but also at home and in the village. Bolo is indispensable to the lives of the Sama in Tawi-Tawi as it served as one of the main tools in almost all of their works.

Knife. The short single-edged and plastic-handled knife or *laring* in Figure 1.b was used by the mat weaver to slice and weed off the spiny margins of a *pandan* leaf.

Figure 1.b

Local Tools Used in Sama Mat Weaving: Knife or Laring to Slice and Weed Off Spines of a Pandan Leaf (Photo taken by the Author in Tandubas, Tawi-Tawi in December 2020)

For the mat weavers, the knife, as shown in Figure 1.b, is much preferred for slicing a *pandan* leaf over a bolo because of its lightweight. This sharp-cutting tool was available in the local market at a low price. The Sama widely used this in mat weaving, seaweed farming, and most of their daily activities at home or outdoors. Knife has certainly become an integral daily tool among Sama cultural communities.

Cooking Pot. The large aluminum cooking pot or *lappoh* in Figure 2.c was used by the mat weaver to hold raw *pandan* leaves for boiling in fresh water. It was 12 inches tall with an opening diameter of 12 inches.

Figure 1.c

Local Tools Used in Sama Mat Weaving: Cooking Pot or Lappoh to Hold Pandan Leaves for Boiling in Water (Photo taken by the Author in Tandubas, Tawi-Tawi in December 2020)

This cooking pot in Figure 1.c was heated in a traditional wood-burning clay stove to boil *pandan* leaves in hot water. The Sama also used this to hold and cook agricultural produce such as root crops and even fishery harvests like seashells. A pot of this size was available in the local market at an affordable price. Small sizes of the cooking pots were mainly used to cook rice.

Traditional Stove. A traditional wood-burning clay stove or *lappohan* in Figure 1.d was used by the mat weaver to hold up a cooking pot when boiling the *pandan* leaves.

Figure 1.d

Local Tools Used in Sama Mat Weaving: Traditional Stove or Lappohan to Heat a Pot of Pandan Leaves in Water (Photo taken by the Author in Tandubas, Tawi-Tawi in December 2020)

This traditional stove in Figure 1.d had chairs in a triad that could support the pot. It was about 3 ft long and 1 ft wide. This stove was the traditional cooking equipment of the Sama, where fuelwood was fed in it. This was used not only to heat *pandan* leaves or water but also other eatables that needed to be cooked. It was purchased in a local market at around 5 USD. For a long time, old stoves were originally made of mere rocks, where twigs and wood served as biomass fuel. Today, clay stoves were gradually replaced by metallic stoves fueled by gas. Modern stoves are powered by integrated electric heating technology to cook food.

Weight. The circular wooden bar weight or *panganggipit* in Figure 1.e was used by the mat weaver to press down *pandan* leaves in a cooking pot so that they would submerge in the boiling water.

Figure 1.e

Local Tools used in Sama Mat Weaving: Weight or Panganggipit to Press Down Pandan Leaves or Tepo (Photo taken by the Author in Tandubas, Tawi-Tawi in December 2020)

A much heavier concrete, as shown in Figure 1.e, was put above the wooden bar to increase the heaviness of the weight. The Sama themselves created the wooden bar and the concrete out of readily available materials. Spare metal weight could also be an alternative to concrete weight. However, the bar should be wooden not to impair the surface of any *pandan* leaves. A wooden bar weight was also needed to press down a certain part of the *tepo* while they were weaving.

***Pandan* Slitter**. The *pandan* slitter or *jangatan* in Figure 1.f was used by the mat weaver to slit or slice boiled *pandan* leaf strands lengthwise into long uniform strips.

Figure 1.f

Local Tools Used in Sama Mat Weaving: Pandan Slitter or Jangatan to Strip a Cooked Pandan Leaf Strand (Photo taken by the Author in Tandubas, Tawi-Tawi, in December 2020)

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This slitter in Figure 1.f had eight sharp metal teeth, roughly 4 mm away from each other, epoxied to its bamboo handle. Consequently, seven *pandan* strips could be produced in every slicing of a *pandan* leaf strand. Each tooth was about 1cm long and attached at one end part of the slitter. These teeth determined the size and the uniformity of the *pandan* strips that would be woven. Thus, this tool is crucial in achieving the fineness of the woven *tepo*. It was created by the mat weaver out of a small portion of a bamboo stem and a metal sheet with the aid of metal sheers or bolo, nylon string, and epoxy glue. To use this tool, firmly hold its handle by one hand where its teeth should puncture the cooked *pandan* leaf strand at 1-inch allowance from the end part of the leaf. Then, the *jangatan* would be moved across, slashing the leaf strand into strips. The number and interval of the teeth of a *jangatan* depends on the type of the *tepo* to be woven. The one created and used for the rear *tepo* had a longer interval and a shorter number of metal teeth than those for the front *tepo*. This is because the plain white rear *tepo* did not need to be as narrow as the colorful front *tepo*, according to the mat weaver. Meanwhile, the Metals Industry Research and Development Center (MIRDC) of the Department of Science and Technology (DOST) designed and developed a manually operated device for slitting *pandan* leaves. This assembly comprises metal blades to cut a leaf and an adjustable spacer for its desired even width (Limson & Luces, 2015). However, this device has not yet reached Tawi-Tawi.

***Pandan* Presser**. The huge wooden *pandan* presser, locally called *paggosan* in Figure 1.g was used by the mat weaver to press boiled or dried *pandan* strips.

Figure 1.g

Local Tools Used in Sama Mat Weaving: Pandan Presser or Paggosan to Compress Pandan Strips (Photo taken by the Author in Tandubas, Tawi-Tawi in December 2020)

This presser in Figure 1.g was a cylindrical log whose length (or altitude when vertical) was 9.9 ft and diameter was 1.5 ft. Its weight was unknown, but it was heavy enough to press something under high pressure that it could break one's finger bones when accidentally caught by the presser. It was horizontally positioned above a pair of large identical wooden blocks as braces near both ends of the cylinder. The upper sides of both braces were carved parabolically open upward to allow swaying of the cylindrical presser back and forth when force was applied to it. Each brace was supported by a pair of large 2.25 ft wooden pegs 4.5 ft away from each other. Each square side of the wooden block was 8 inches long. Both pairs of braces were 1.75 ft above the ground and 5 ft away from each other. To use the *paggosan*, a weaver would choose one of its sides where she could place the cooked or dried *pandan* strips. The wooden cylinder would be pushed a little to sway while placing the *pandan* strips in the curved brace.

Pressing of *pandan* strips by the *paggosan* is done by the mat weaver for around 3 to 5 minutes only. The locals built a shed around it to provide shelter for the weavers or users from rain or sunny weather. Early dwellers created these traditional wooden *pandan* pressers for their mat weavers in town, and one to two pressers were maintained in a strategic area. Today, these structures serve as cultural landmarks of the Sama on the island town. Meanwhile, the slitting device designed and developed by DOST MIRDC has a presser assembly. This was a presser-slitter device for *pandan* leaves. The presser assembly flattens the *pandan* leaves into quality pounded and softened leaf-end products (Limson & Luces, 2015).

Bucket. This white bucket or *baldi* in Figure 1.h was used by the mat weaver to hold boiled *pandan* strips for soaking in seawater for the first day and in fresh water for the succeeding two days.

Figure 1.h

Local Tools used in Sama Mat Weaving: Bucket or Baldi to Hold Cooked Pandan Strips in Water (Photo taken by the Author in Tandubas, Tawi-Tawi in December 2020)

This bucket in Figure 1.h stood 14 inches with a diameter of 11.5 inches in its upper hole. This had a handle to help a weaver carry it despite being heavy when loaded with water. Originally, this was a container for 20 L of diesel engine oil. Due to the durability and quality of the container, it was reused or recycled to hold water for daily use in washing. The Sama needed to collect water in buckets from deep wells since they did not have a pipeline system of water supply. Most of the available buckets in the local market were ordinary and deficient in quality. Thus, the Sama preferred to use this heavy-duty container over local buckets.

Bamboo scalp scratcher. The bamboo head-scratcher or *kuhut* in Figure 1.i was used by the mat weaver to detach dried *pandan* strips from its strand.

Figure 1.i

Local Tools Used in Sama Mat Weaving: Bamboo Scratcher or Kuhut to Detach and Straighten Pandan Strips (Photo taken by the Author in Tandubas, Tawi-Tawi in December 2020)

This tool in Figure 1.i was 8 inches long and 1.5 inches wide, curved at one end. It was used by gradually ripping off intact *pandan* strips from their strands. This was also used to straighten up creased *pandan* strips for smooth weaving of the *tepo* by the mat weaver. However, ripping and straightening *pandan* strips could also be done by hand without a *kuhut* according to the mat weaver. The Sama traditionally used this tool to scratch itchy scalp.

Cooking Pan. A large aluminum cooking pan or *kawalih* in Figure 1.j was used by the mat weaver to hold white *pandan* strips for boiling and dyeing with a coloring powder locally known as *anjibi*.

Figure 1.j

Local Local Tools used in Sama Mat Weaving: A Cooking Pan or Kawalih to Hold Pandan Leaves for Boiling and Dyeing (Photo taken by the Author in Tandubas, Tawi-Tawi in December 2020)

This cooking pan in Figure 1.j was double-handled and had an opening diameter of 18 inches wide yet shallow, allowing *pandan* strips to be stirred up well by the mat weaver and a boiling-colored solution. Hence, the mat weavers preferred to use this to dye the *pandan* strips over a cooking pot. The pan was heated in the same traditional wood-burning clay. Affordable smaller pans have long handles and are used to cook and/or fry vegetables, fish, and the like.

Needle. A large-sized needle or *jalumin* Figure 1.k was used by the mat weaver to sew the front *tepo* into its underlying rear *tepo*.

Figure 1.k

Local Tools Used in Sama Mat Weaving: Needle or Jalum Used to Sew the Front and Rear Parts of a Tepo Together (Photo taken by the Author in Tandubas, Tawi-Tawi, in December 2020)

This needle in Figure 1.k was a pointed, slender steel 3 inches long where a nylon string could fit its hole at one end. It carried nylon string as the thread to make stitches along certain margins of the front and the rear components of the *tepo*. It was available in the local market at Php 10. The mat weavers recommended that the needle be as large as possible so that it would not easily get broken and that the nylon string could fit its eye. Small-sized needles were widely used for the traditional sewing of cloths and fabrics.

Nylon String. The nylon string or *kurdas* in Figure 1.l was used by the mat weaver as the thread to sew the front *tepo* into its underlying rear *tepo*.

Figure 1.l

Local Tools Used in Sama Mat Weaving: Nylon String or Kurdas as the Thread in Sewing a Tepo (Photo taken by the Author in Tandubas, Tawi-Tawi in December 2020)

This nylon string in Figure 1.l was inserted in the hole of a large needle and pulled off so that both components of *tepo* could be sewn by hand. For the mat weavers, the nylon size did not matter as long as it could fit the needle hole to be used. It was readily available in the local market for a low price per 30 g in one roll approximately 27 m long. Thus, one roll of the nylon string is more than enough to sew both parts of the *tepo*. This was widely used by fisher folks and lads in the village as fishing lines or in making fishing nets.

Ethnoengineering in Mat Weaving

Classical design and procedures in mat weaving among the Sama in Tawi-Tawi mainly include: (1) gathering *pandan* leaves; (2) preparing *pandan* leaf strands; (3) boiling *pandan* leaf strands; (4) making *pandan* strips; (5) bleaching *pandan* strips; (6) dyeing white *pandan* strips; (7) weaving the front and rear *tepo*; and (8) fastening the front and rear *tepo*. The *tepo*, or the traditional mat of the Sama, was double-stranded, having two components: *tepo deyom* or front *tepo* and *tepo lapis* or rear *tepo*. According to the mat weavers, the classical engineering design and procedures involved in weaving both components slightly differed in the following: the type of screw pine or *pandan* selected as raw material, dyeing *pandan* strips using a coloring powder, and the weaving style per se. *Pandan* strips used for the front *tepo* were dyed to the desired colors, while those for the rear *tepo* were left. Weaving *pandan* strips for the front *tepo* was complex and entailed much time, while for the rear *tepo*, it was simpler and faster. Nevertheless, both *tepo* components followed similar techniques and procedures for gathering *pandan* leaves and making white *pandan* strips. While in the wild, the *pandan* leaf was cut from its main stem using a bolo whose leaf spines were weeded off with a knife. These leaves were sliced into strands, arranged, and brought home for clustering, folding, boiling in hot water, and drying. Boiled and dried *pandan* strands were slashed into strips using a slitter; soaked in a bucket of water; pressed using a large wooden presser; and dried under the scorching heat of the sun to make them white. White *pandan* strips were again pressed, and those intended for the front

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tepo were dyed in a colored boiling solution. The dried and pressed *pandan* strips were woven for 1 to 3 weeks depending upon the *tepo* component.

Gathering *Pandan* Leaves. Screw pine or *pandan* was accessed by the mat weavers in the wild along the coastal headland of a village in town. The forested area could be reached by a 45-minute walk from the residential houses. For practical reasons, the mat weavers preferred at least the shrub-sized screw pines over the enormous tree-sized ones. They would collect *pandan* leaves intended for the *deyom* or front component of the *tepo* and those used for weaving its *luwasan* or rear component. Green and mature *pandan* leaves in their stout trunk or main stem were carefully cut using a bolo. It took about five trunks or main stems, each with 16-20 mature leaves. One should be extra cautious when cutting the leaves since these are spiny and could easily puncture one's hands. The mat weavers are advised to wear gloves and boots while cutting the *pandan* leaves. It took them 30 min to cut *pandan* leaves from five trunks where those 1.5-2 *dappa* or (stretched arms) long were selected.

Preparing *Pandan* Leaf Strands. In Figure 2.a, the mat weavers stripped the midrib and edges of a *pandan* leaf using a knife to weed off their spines in a clear and shady area.

Figure 2.a

Classical Designs and Procedures in Sama Mat Weaving: Weeding Off Spines in the Margins and Midrib of a Pandan Leaf (Photo taken by the Author in Tandubas, Tawi-Tawi in December 2020)

According to them, this procedure, as illustrated in Figure 2.a, is locally known as *ngandeleet*. This subsequently divided each leaf into two parts or strands. They needed to eradicate the spines in the forest so they would not be a hassle when bringing the leaves home. Spineless *pandan* leaf strands in Figure 2.b were gathered and arranged over a dried coconut palm leaf with at least a pair of wooden pegs erected on the ground from both sides.

Figure 2.b

Classical Designs and Procedure in Sama Mat Weaving: Arranging Spineless Pandan Leaf Strands over a Coconut Leaf (Photos taken by the Author in Tandubas, Tawi-Tawi in December 2020)

These cut *pandan* leaves and dried coconut palms were tied together using a nylon rope, as seen in Table 2.b, to prevent scattering. Each mat weaver brought a bunch of 160-200 raw *pandan* leaf strands as they returned home.

Boiling *Pandan* Leaf Strands. Eight to ten *pandan* leaf strands of the same variety were clustered at home. These were then folded and tied onto themselves, starting at 1 *hakka* (hand span), and one part was laid over another until it reached the end. These strands were fixed and tied in a way that they would stick together in the cluster like in Figure 2.c.

Figure 2.c

Classical Designs and Procedures in Sama Mat Weaving: Folding of Pandan Leaf Strands onto themselves (Photo taken by the Author in Tandubas, Tawi-Tawi in December 2020)

This folding process, as mentioned earlier, was repeated for the rest of the leaf strands, which yielded 16-20 pleated clusters of leaf strands, as shown in Figure 2.c. These were set aside while preparing the large cooking pot, fresh water in a container, wooden and concrete weights, a traditional wood-burning clay stove, firewood, and a lighter. Five folded clusters of *pandan* leaf strands were placed in the pot nearly filled with fresh water.

Firewood was burned and fueled in the clay stove to heat the pot and boil the *pandan* leaf strands with fresh water, as seen in Figure 2.d.

Figure 2.d

Classical Designs and Procedures in Sama Mat Weaving: Boiling Pandan Strands in a Pot of Scalding Water (Photos taken by the Author in Tandubas, Tawi-Tawi, in December 2020)

Wooden weight under a concrete weight in Figure 2.d was put over the *pandan* leaf clusters in the heated cooking pot to push them down. The *pandan* leaf strands for the front component of the *tepo* were boiled in hot water for 10 minutes, but those for the rear part were boiled for up to 20 minutes

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to make them soft and pale. The subsequent and remaining batches of the *pandan* leaf strands were boiled in the same pot of hot water while ensuring that water was constantly added and boiled. These boiled *pandan* leaf strands were set aside to cool, as displayed in Table 4.c of the Ethnoscience section.

Making *Pandan* Strips. Boiled and air-dried *pandan* leaf strand was stripped by a mat weaver using a locally made slitter known as *jangatan*, as shown in Figure 2.e.

Figure 2.e

Classical Designs and Procedures in Sama Mat Weaving: Stripping Boiled and Dried Pandan Strands into Pieces (Photo taken by the Author in Tandubas, Tawi-Tawi in December 2020)

The bamboo handle of this local slitter, as used in Figure 2.e, was held so that its eight sharp metal teeth punctured the near end of the *pandan* leaf strand. In this position, the slitter was moved across the leaf strand, slashing it into seven narrow strips, each about 4 mm wide. About 1,120-1,400 pieces of *pandan* strips could be produced and further grouped into eight bunches. Every bunch had 140-175 pieces of *pandan* strips, which would be brought to a huge community wooden presser, locally known as *paggosan*, built in the village. A bunch of *pandan* strips was placed over one of the two wooden curve braces of the presser. The wooden cylindrical log in Figure 2.f was pushed to sway back and forth while repetitively pressing the *pandan* strips beneath it under high pressure.

Figure 2.f

Classical Designs and Procedures in Sama Mat Weaving: Pressing Boiled Pandan Strips beneath a Wooden Presser (Photo taken by the Author in Tandubas, Tawi-Tawi, in December 2020)

This pressing of *pandan* stripes in Figure 2.f made it firm and compact. The presser was constantly pushed to prevent it from ceasing to sway. Pressing of the *pandan* strips took around 3-5 minches It was suggested by the mat weaver that extra caution should always be observed when the presser is swaying to avoid injuring one's fingers by accident. The other seven bunches also underwent this pressing technique one after another.

Bleaching *Pandan* Strips. The bunches of pressed *pandan* strips in Figure 2.g were brought home, soaked in a bucket nearly filled with seawater for the first day, and changed with fresh water for the succeeding two days. This soaking process is essential for bleaching the *pandan* strips.

Figure 2.g

Classical Designs and Procedures in Sama Mat Weaving: Soaking Pressed Pandan Strips in a Bucket of Water (Photo taken by the Author in Tandubas, Tawi-Tawi in December 2020)

After three days, these soaked *pandan* strips, as shown in Figure 2.g, were removed from the bucket and washed with fresh water. The wet strips were arranged and hung overnight to receive atmospheric dew. The next day, the air-dried strips in Figure 2.h were dispersed in fenced grassland for another 72 hours or 3 days.

Figure 2.h

Classical Designs and Procedures in Sama Mat Weaving: Dispersing Air-Dried Pandan Strips in a Grassland for Drying (Photo taken by the Author in Tandubas, Tawi-Tawi, in December 2020)

The *pandan* strips shown in Figure 2.h were dispersed in grassland to get exposed to high temperatures during the daytime and atmospheric dew at nighttime. Every day, the mat weaver monitored the *pandan* strips to prevent them from turning orange due to too much heat acquired. This was the final step: the *pandan* strips would turn white from the pale green after being boiled. The thoroughly dried white *pandan* strips were gathered, arranged, and tied in a bunch. These were brought to the community wooden presser for pressing in 3-5 minutes. This was the second time the *pandan* strips were pressed using the same wooden presser. After pressing, the white strips were brought home. These were untied like the ones shown in Figure 1.h, and then each strip was detached from its strand using a spatula-like bamboo tool locally known to the community as *kuhut*.

Dyeing White *Pandan* Strips. White *pandan* strips used for the front component of the *tepo* were dyed with coloring powder known as *anjibi*, available in the local market at Php 80 for 3 tbsp. According to the mat weavers, colors in *tepo* are important as these could affect the design and market price. The materials needed in dyeing white *pandan* strips were prepared, such as coloring powder, a

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large cooking pan, a frying spatula or any slender wood, fresh water, a wood-burning stove, firewood, and a lighter. Firewood was burned and fueled in the stove to heat and boil freshwater half-filled in a cooking pan. The coloring powder was mixed, stirred, and dissolved in the boiling water using a spatula or any slender wood. Then, white *pandan* strips were soaked, boiled, and stirred in this solution for 20 minches When the boiling solution dried a little, the pan was immediately removed from the stove and let cool. The colored *pandan* strips were removed from the pan and arranged over an empty sack. The remaining solution was either thrown or reused to enhance the brightness of another coloring solution. The mat weavers also mixed colors to explore and produce new pigments for the white *pandan* strips.

The colored *pandan* strips were hung inside the house overnight to get dry. According to the mat weaver, it was prevented from getting exposed to sunlight so that its color would not pale. The next day, these colorful *pandan* strips are found in Figure 2.i were organized and brought to the wooden presser for pressing the third time to make it firmer and more compact.

Figure 2.i

Classical Designs and Procedures in Sama Mat Weaving: Organizing Colored Pandan Strips after Air Dried (Photo taken by the Author in Tandubas, Tawi-Tawi in December 2020)

Figure 1.i shows three different bright colors of dyed *pandan* strips, such as red, purple, and yellow. These were air-dried, organized by the weaver, and prepared for weaving.

Weaving the Front and the Rear *Tepo*. Colored *pandan* strips were used to weave the front component of a *tepo*, while white strips were intended for its rear part. The mat weavers would always weave the front *tepo* first to estimate the size of its corresponding rear *tepo*. Weaving was done by hand while the mat weaver sat over the *tepo* on the floor. The initial stage of weaving a *tepo* called *pagbatul* would start with two *pandan* strips, where one was placed perpendicular over the other at middle points and twisted through a certain pattern. Within these two twisted strips, other *pandan* strips were gradually inserted, folded, and twisted piece by piece through the same pattern to weave and expand the first layer of the *tepo*. For the mat weaver, this stage was crucial as it determined the design of the finished *tepo*.

In every layer of weaving the *pandan* strips into *tepo*, a single strip was pulled off and crossed over at least 10 pairs of upper and lower alternate strips with both hands. This process was repeated while techniques such as skipping and twisting were applied along the way to give designs to the *tepo*. *Pandan* strips of the same color were added in clusters and manually woven until the desired length of the *tepo* was achieved. All other desired colors of *pandan* strips were ensured to have already been added and woven upon completing the first layer of the *tepo*. Succeeding left and right layers of the *tepo* were woven while considering the previously applied techniques. *Pandan* strips were twisted at the starting and the ending parts of the *tepo* in every layer to ensure that the woven strips would remain intact. A wooden weight was placed over a thin wooden bar to press down certain parts of the *tepo* while weaving the *pandan* strips for convenience. Should there be *pandan* strips that crease, these could be straightened up with the fingernails of the mat weaver or by using *kuhut*. Any short *pandan* strip in an unfinished *tepo* could be extended with another similar strip to be weaved, overlapping the shorter strip.

Various techniques were applied by the mat weavers while weaving a front *tepo*, such as twisting and skipping strips to alter the strip's direction and design. In the skipping technique seen in Figure 2.j, three strips were skipped when weaving the other strips to create frame-like designs known to them as *sasa*, which could be done within the *tepo* or near its opposite sides.

Figure 2.h

Classical Designs and Procedures in Sama Mat Weaving: Applying the Skipping Technique in Weaving Pandan Strips (Photo taken by the Author in Tandubas, Tawi-Tawi in December 2020)

The twisting technique in Figure 2.j was done by the mat weaver to change the direction of woven strips, thereby creating a certain effect in some designs of the *tepo*. The number of x's or *lunggihin* in the *tepo* design should be accounted for accurately so that twisting can be done so that no single strip goes in a different direction. A *tepo* design that did not involve twisting was called *kusta* by the mat weavers. Other complex geometric designs and styles were woven for the front *tepo*. Some were called *sekoh-sekoh* and *kalis-kalis*, characterized by their zigzag patterns. All these were either copied from existing *tepo* designs or merely a product of a weaver's imagination. It took 10 to 14 days for a full-time mat weaver to finish weaving a front *tepo*, depending upon the complexity of its design.

On the other end, the rear component of a *tepo* was also weaved by hand using white *pandan* strips. The conventional weaving procedures were followed, such as sitting on the floor while weaving, using *pagbatul*, working on every strip, and crossing pairs of alternate strips, as shown in Figure 2.k.

Figure 2.k

Classical Designs and Procedures in Sama Mat Weaving: Weaving of Pandan Strips for the Rear Tepo (Photo taken by the Author in Tandubas, Tawi-Tawi in December 2020)

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Figure 2.k displays alternate *pandan* strips being weaved. When a *pandan* strip gets creased, it can be straightened and extended with a shorter strip like those in the front *tepo*. Weaving the rear *tepo* was simple and limited only to the procedures discussed. The mat weaver applied no other techniques, such as twisting for design and skipping. They aimed to weave the *tepo* longer and wider than its front component by at least 1 *hakka* or hand span on all sides. Wooden weights were also used to avoid hassle while weaving and sitting on the *tepo*. A mat weaver only took about 1 week to finish weaving the rear *tepo*.

Fastening the Front and the Rear *Tepo*. After weaving both components of the *tepo*, extra strips along its two opposite sides were trimmed by the mat weaver using scissors. Some mat weavers placed their front and rear *tepo* under a floor carpet for half a day to straighten up. Some would proceed to sew both components of the *tepo*. This was initially done by spreading out and placing the front *tepo* over its rear component. The four sides of both *tepo* components were folded towards each other, forming a rectangle. Small wooden weights were placed over the four folded sides of both *tepo* parts to temporarily fasten them. A nylon string and a 3-inch needle were prepared to attach both components of the *tepo*. The string was inserted and tied to the needle's eye. Using this, both components of the *tepo* were sewn to each other by hand, producing a firmer mat like in Figure 2.l.

Figure 2.l

Classical Designs and Procedures in Sama Mat Weaving: Sewing the Front and the Rear Tepo Components (Photo taken by the Author in Tandubas, Tawi-Tawi in December 2020)

Shown in Figure 1.l is a product of the Sama traditional mat, locally known as *tepo*, made from indigenously processed leaves of a *pandanus* plant. It underwent a meticulous process of boiling, stripping, bleaching, dyeing, weaving, and fastening.

Ethnomathematics in Mat Weaving

Mathematical ideas in mat weaving among the Sama in Tawi-Tawi are classified into three domains: (1) primitive measurement, (2) arithmetic calculation and algebra, and (3) geometry. Mathematical ideas in mat weaving, from preparing *pandan* leaves to weaving the *tepo*, could be classified under primitive measurement, arithmetic calculation algebra, and geometry. Ethnomathematics of mat weaving are discussed for the front or the rear *tepo* in making, soaking, pressing, drying, dyeing, and weaving the strips.

Primitive Measurement. Two primitive units of length measurement, such as *hakka* (hand span) and *dappa* (stretched arms), were used in the Sama mat weaving. In addition, another unit of length measurement utilized in mat weaving was *insih*, derived from "inch" of the US System of measurement, equivalent to 1/12 ft or 2.54 cm in the Metric system. For the Sama, *insih* was equal to the length of the distal phalanx of a middle finger, as in Figure 3.a.

Figure 3.a

Classical Designs and Procedures in Sama Mat Weaving: Sewing the Front and the Rear Tepo Components (Photo taken by the Author in Tandubas, Tawi-Tawi in December 2020)

By convention, 1 *hakka* was equivalent to 8 insih, and that 1 *dappa* was roughly 72 insih. These primitive units of measurement were reliant on body parts and were used in mat weaving for measuring lengths in some occurrences such as:

1.5-2 *dappa* (108-144 *insih*) of *pandan* leaves were selected to make *pandan* strands or strips; folding clustered *pandan* strands onto themselves started at 1 *hakka* or 8 *insih* in length; and the rear *tepo* was woven in a way longer and wider by about 1 *hakka* or 8 *insih* on all four sides of its corresponding front *tepo*.

Arithmetic Calculation and Algebra. Calculations in mat weaving involved simple multiplication, division, ratio, and proportion on the number of *pandan* leaves, strands, and indigenously processed strips. Measurements were also accounted for by the mat weavers' boiling, pressing, and dyeing of *pandan* leaf strands and strips. Parabola and damped harmonic motion were manifested in the *pandan* presser. The following were calculations and some algebra concepts found in mat weaving.

Each trunk or main stem of a screw pine was likely to have 16-20 mature leaves. Thus, five trunks would have around 80-100 mature leaves by simple multiplication. Moreover, each *pandan* leaf, whose spines were already weeded off, would be sliced in half, producing two symmetric strands. This gave the whole-to-part ratio of 1:2. So, five trunks of screw pine having a total of 80-100 mature leaves would yield 160-200 *pandan* strands.

In addition, eight to 10 *pandan* strands were grouped and folded onto themselves. Hence, around 20 pleated clusters of leaf strands could be made by division operation from 160-200 strands. Five pleated clusters of *pandan* strands for the front and rear *tepo* were also boiled for 10 and 20 minutes, respectively. *Pandan* strands were boiled in fresh water and filled in a large cooking pot at around three-quarters of the pot's capacity.

A *pandan* slitter, having eight teeth, could make seven *pandan* strips from a leaf strand. By multiplication, 1,120-1,400 *pandan* strips could be made from 160 to 200 strands. The strip in Figure 3.b was 4 mm in width and 72 *insih* in length.

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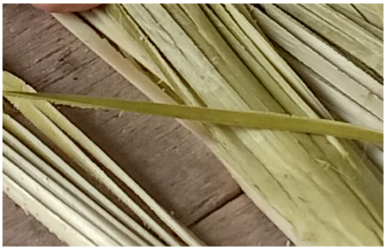
Figure 3.b

Mathematical Ideas Exhibited in Sama Mat Weaving: Pandan Strip 4 mm Wide (Photo taken by the Author in Tandubas, Tawi-Tawi in December 2020)



The upper side of each wooden brace of the *pandan* presser in Figure 3.c was carved in an open upward parabola represented by the quadratic equation in standard form x2 = 4ay, where 4a is the length of the latus rectum.

Figure 3.c

Mathematical Ideas exhibited in Sama Mat Weaving: Pandan Strip 4 mm Wide (Photo taken by the Author in Tandubas, Tawi-Tawi in December 2020)

Pushing the cylindrical presser in Figure 3.d would make it sway and exhibit a damped harmonic motion.

Figure 3.d

Mathematical Ideas in Sama Mat Weaving: Damped Harmonic Motion of a Presser Modeled by Sinusoidal Function (Photo taken by the Author in Tandubas, Tawi-Tawi in December 2020)

The oscillating presser from its resting position at time *t* can be modeled by the sinusoidal function $f(t) = ae^{-ct} \sin \omega t$ where *c* is a damping factor, $|a|$ is the initial displacement, and $2\pi/\omega$ is the period.

A bunch of 140-175 *pandan* strips took 3 to 5 minutes of pressing. So, eight bunches of these strips would take around 24-40 minutes to be pressed in the *pandan* presser.

According to the mat weaver, 3 tbsp of coloring powder was needed to dissolve in a boiling freshwater half-filled cooking pan. In the case of making a new pigment out of two distinct colors, 1.5-2 tbsp of each powder would be mixed in the boiling water. Three tbsp of the pigment was purchased at Php 80, which gave a unit price of Php 27 per tbsp. The relation between the amount of the powder in *x* tbsp and its corresponding price in *y* Php can be represented by $y = 80\ x/3$, where $x > 0$. For example, 4 tbsp of the pigment can be purchased at Php 107 by plugging $x = 4$ in the *y* equation.

It took around 6 days for a mat weaver to finish weaving white *pandan* strips for a rear *tepo* but around 12 days to weave colored strips for a front *tepo*. The time to finish weaving a front *tepo* is roughly twice that of its rear counterpart due to the twisting and skipping techniques applied in the latter. It took around three weeks to complete a finished *tepo* product.

The concepts of Geometry found in the Sama mat weaving involved basic figures and their relationships. Crisscrossing and weaving of the *tepo* strips illustrated betweenness, collinearity, perpendicularity, parallelism, and angle pairs. The large wooden presser further illustrated the circle and cylinder. On the *tepo* designs, key geometric relationships such as congruence, symmetries, and isometries along some polygons emerged. Some of these were also found in related studies (De Las Peñas et al., 2014; Pradhan, 2020; Solaiman et al., 2017). The following were geometric concepts that emerged in the mat weaving of the Sama in Tawi-Tawi.

Basic geometric figures such as points, lines, and angles were formed by the crisscrossing of *tepo* strips like in Figure 3.e.

Figure 3.e

Mathematical Ideas Exhibited in Sama Mat Weaving: Points and Lines Formed in the Crisscrossing of Tepo Strips (Photo taken by the Author in Tandubas, Tawi-Tawi, in December 2020)

Also, some local tools used in mat weaving could represent points or lines. Betweenness and collinearity of points were seen in the woven *tepo*. Angle pairs such as adjacent angles, vertical angles, complementary angles, and supplementary angles were also portrayed in the designs of *tepo*.

Perpendicularity in the woven *tepo* was seen in two *pandan* strips folded and twisted together at the very start of creating the mat up to finishing it. Consequently, right angles were formed. Weaving

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tepo was done by taking one strip and crossing over 10 pairs of upper and lower parallel alternate strips. *Pandan* strips were woven in a crisscross pattern that created intersecting, perpendicular, and parallel lines or saysig throughout the *tepo*.

Convex polygons were exhibited in different designs made by *pandan* strips woven into *tepo*. Some were isosceles, such as right triangles, rectangles, squares, rhombuses, parallelograms, and hexagons. Further, symmetries and congruences among these polygons were also manifested, just like the square designs of the *tepo* in Figure 3.f.

Figure 3.f

Mathematical Ideas exhibited in Sama Mat Weaving: Square Designs of a Tepo Displaying Symmetry (Photo taken by the Author in Tandubas, Tawi-Tawi in December 2020)

These mathematical concepts and processes are also contained in Maranao weaving designs (Solaiman et al., 2017).

In Figure 3.g, the front *tepo* has a length (l) of 8 *hakka* and width (w) of 4 *hakka*, while its rear part was 10 *hakka* long and 6 *hakka* wide.

Figure 3.g

Mathematical Ideas Exhibited in Sama Mat Weaving: Rectangle Mensuration in a Tepo (Photo taken by the Author in Tandubas, Tawi-Tawi in December 2020)

The smaller *tepo* has a perimeter (P) = 2l + 2w = 2(l + w) = 2(8 *hakka* + 4 *hakka*) = 2(12 *hakka*) = 24 *hakka*; the larger *tepo* has P = 2(10 *hakka* + 6 *hakka*) = 2(16 *hakka*) = 32 *hakka*. The area (A) of the smaller *tepo* is lw = (8 *hakka*) (4 *hakka*) = 32 $hakka^2$; the larger *tepo* has A = (10 *hakka*)(6 *hakka*) = 60 $hakka^2$.

A circle can be found on the two sides of a *pandan* presser in Figure 3.h.

Figure 3.h

Mathematical Ideas Exhibited in Sama Mat Weaving: Circle in a Cylindrical Wooden Presser (Photo taken by the Author in Tandubas, Tawi-Tawi in December 2020)

The radius (r) of each circle was 1.5 ft long. Thus, it has diameter (d) = 2r = 2 (1.5 ft) = 3 ft; circumference (C) = πd = π (3 ft) = 3π ft ≈ 3(3.14) ft ≈ 9.42 ft; and area (A) = πr^2 = π $(1.5\text{ft})^2$ = π (2.25 ft^2) = 2.25π ft^2 ≈ 2.25(3.14) ft^2 ≈ 7.07 ft^2. Circles could also be found in the openings of the cooking pot, bucket, and cooking pan, whose radii were 12 inches, 10 inches, and 14 inches, respectively.

The large wooden presser was a cylinder whose radius (r) was 1.5 ft long and height (h) was 9.9 ft. It has a total surface area (TSA) = $2\pi r^2 + 2\pi rh = 2\pi r (r + h)$ = 2π (1.5ft) (1.5ft + 9.9ft) = 3π ft (11.4 ft) = 34.2π ft^2 ≈ 34.2 (3.14) ft^2 ≈ 107.4 ft^2; and volume (V) = $\pi r^2 h$ = π $(1.5\text{ ft})^2$ (9.9 ft) = π (2.25 ft^2) (9.9 ft) = π (22.3 ft^3) = 22.3π ft^3 ≈ 22.3 (3.14) ft^3 ≈ 70.0 ft^3. In Nepalese mat weaving, geometrical ideas on parallelograms and cylinders were also exhibited (Pradhan, 2020).

The colorful *tepo* designs demonstrated geometric symmetry and rigid motions or isometries such as rotation, reflection, and translation like that in Figure 3.i.

Figure 3.i

Mathematical Ideas exhibited in Sama Mat Weaving: Geometric Rotation of Right Triangles in a Tepo Design (Photo taken by the Author in Tandubas, Tawi-Tawi in December 2020)

The pink and green right triangles in the *tepo* design in Figure 3.i manifested a geometric rotation at a point. The color symmetry and rigid motions embedded in the mat design are also established in the findings of De Las Peñas and colleagues (2014).

Ethnoscience in Mat Weaving

Concepts and ideas of the Sama on mat weaving which relate to science concepts can be found in the following: (1) some properties of screw pines; (2) softening of *pandan* strands; (3) bleaching of *pandan* strips; (4) pressure in *pandan* strips; (5) periodic motion of the presser; and (6) dyeability of *pandan* strips. The handwoven *tepo* mat of the Sama in Tawi-Tawi was made from *pandan* or screw pine (Pandanus tectorius). It was a double-stranded mat where both the plain white rear and the colorful front components utilized distinct varieties of screw pines as raw materials. The Sama used the term *pandan* to refer to all the varieties of screw pines in the town's headlands. Thus, they did not have any specific name for each variety. Two of which were widely used in weaving both components of the *tepo*: (1) *pandan* luwasan or the screw pine for the rear component; and (2) *pandan* deyom or screw pine for the front part. Both *pandan* varieties' leaves were green, with spines along margins and midribs. These leaves were indigenously processed through boiling, stripping, soaking, drying, and pressing to make white and colorful strips woven by hand. The finished *tepo* was used by the Sama not only as a mat and ornament but also as a bag, hat, and the like.

Some Properties of Screw Pines. A distinct variety of pandanus or screw pines was used by the mat weaver for each of the two components of the *tepo* mat. The screw pine in Figure 4.a was used for the rear *tepo*, which could grow about 80 ft or as tall as a coconut tree, having thick stilt roots.

Figure 4.a

Science Ideas in Sama Mat Weaving: A Pandanus Tree Used for the Rear Tepo (Photo taken by the Author in Tandubas, Tawi-Tawi, in December 2020)

But for practical reasons, the mat weavers would always look for shorter screw pines of this variety. Its thick leaves were spiny along its margins and midribs and about 2 *dappa* (roughly 12 ft) long. On the other hand, the stout screw pine in Figure 4.b, was intended for the front *tepo*, which stood approximately 4 ft or the size of a shrub.

Figure 4.b

Science Ideas in Sama Mat Weaving: A Pandanus Shrub Used for the Front Tepo (Photo taken by the Author in Tandubas, Tawi-Tawi, in December 2020)

The leaves were also spiny but soft and around 1 *dappa* (or about 6 ft) in length. Its spines should be weeded off as these were unnecessary when weaving the *tepo*. Depending upon its variety, the tropical screw pines are classified as either shrub or tree. These are native to the Pacific islands and parts of Southeast Asia and northern Australia (Miller et al., 2010; Thompson et al., 2006). The screw pines intended for the front and the rear *tepo* components were shrub and tree, respectively. Other types of screw pine in town did not have spines, but this variety was so rare. Regardless of their species, the leaves were dark green, while the fruits were green or orange but inedible. Nevertheless, there are species of screw pine whose fruits are edible (Miller et al., 2010; Thompson et al., 2006). The main stem or trunk had 15-20 mature leaves. These plants grew in the wild along the coastal headlands of the town. Pandanus can grow in elevations of sea level from 20-600 m or higher, having a stem growth rate of 2-80 cm annually. These plants can control coastal erosion, windbreak, soil fertility, shade, shelter, and nesting (Thompson et al., 2006).

Softening of *Pandan* Strands. The spineless *pandan* leaf strands became soft yet firm after being boiled in a large aluminum cooking pot of scalding fresh water over a lighted wood-burning stove. *Pandan* leaf fibers are naturally strong. If treated to a boiling process, the leaves yield straw that is much stronger and more durable (Miller et al., 2010). For the mat weavers, the *pandan* leaves intended for the rear component of the *tepo* were heated for 20 minutes or longer due to their thick texture. However, those soft leaf strands for the front *tepo* were boiled for only 10 minches Boiling the leaf strands of *pandan* caused the previously thick dark green *pandan* leaves to become pale green and soft, as in Figure 4.c.

Figure 4.c

Science Ideas in Sama Mat Weaving: Softened Pandan Leaf Strand After Having been Boiled (Photo taken by the Author in Tandubas, Tawi-Tawi, in December 2020)

Moreover, it was observed that the boiled *pandan* leaf strands were not torn easily and that friction was reduced. That is why when these strands were stripped manually with a local *pandan* slicer, the mat weaver would not get any friction burn in the fingers, especially when it was done correctly.

Bleaching of *Pandan* Strips. For the mat weaver, the 3-day sun drying of the pale green stripped *pandan* leaves was the primary factor that could bleach them white like in Figure 4.d.

Figure 4.d

Science Ideas in Sama Mat Weaving: Pandan Strips Bleached White After Three Days of Sun Drying in the Grassland (Photo taken by the Author in Tandubas, Tawi-Tawi, in December 2020)

Drying occurred in fenced grassland, where these strips were dispersed over fixed days and nights. The mat weaver suggested that the drying period should not be longer than 5 days to prevent these *pandan* strips from turning yellow to pale orange. Sun drying causes substantial color degradation in dried herbs provoked by damaging the green pigment known as chlorophyll (Thamkaew et al., 2021). Before drying these strips in the sun's scorching heat, they were pressed beneath a large wooden presser and then soaked. Soaking was done in a bucket of seawater for a day and in fresh water for the succeeding two days. Certain varieties of pandanus used for producing fine white mats in Tonga also used seawater to bleach the strips white (Thomson et al., 2006). After the 3-day soaking, the *pandan* strips were still pale green but much lighter.

Pressure in *Pandan* Strips. *Pandan* strips in Figure 4.e became flat yet firm upon being pressed beneath a large log locally known as *paggosan*.

Figure 4.E

Science Ideas in Sama Mat Weaving: Pressed White Pandan Strips became Fine and Firm (Photo taken by the Author in Tandubas, Tawi-Tawi, in December 2020)

Such condition of the fine and firm *pandan* strips shown in Figure 4.E was achieved due to the pressure from a roller press that compressed the material into sheet compacts according to Wennestrum (2000) as cited in Limson and Luces (2015). Pressure was applied on these strips as the mat weaver pushed the wooden presser back and forth for about 5 minutes. For the mat weaver, air-dried *pandan* strips softened up easily in the presser so that they get flat, fine, and firm compared to sun-dried strips. Indeed, air-dried *pandan* leaves have the best-pressed condition as they can reach the maximum potential for flatness, while sun-dried leaves show cracks when compressed (Limson & Luces, 2015). According to the mat weaver, the sounds produced during pressing meant that the strips still needed much pressure from the *paggosan*. When pressing became silent, the strips were removed as these were said to have received enough pressure.

Periodic Motion of the Presser. Pushing the cylindrical presser in Figure 4.f would make it sway back and forth but would cease oscillating after a few seconds.

Figure 4.f

Science Ideas in Sama Mat Weaving: Periodic Motion Exhibited by the Wooden Presser (Photo taken by the Author in Tandubas, Tawi-Tawi in December 2020)

For the presser to keep swinging, it had to be pushed by the mat weaver from time to time. It was observed that greater push applied on the oscillating presser resulted in an increased acceleration. Further, decreasing the force on the presser caused a decrease in the acceleration. This is consistent with Newton's Second Law of Motion or the law of acceleration. The periodic swaying of the presser illustrates a damped harmonic motion. If damping is small, the period and frequency are nearly the same, while the amplitude gradually decreases. This occurs because the non-conservative damping force removes energy. However, if damping is large, the oscillation slows until it reaches equilibrium (Serway & Jewet, 2004).

Dyeability of *Pandan* Strips. The colorfully dyed *pandan* strips in Figure 4.g were previously dried and pressed in a wooden presser before being dyed in a solution.

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Figure 4.g

Science Ideas in Sama Mat Weaving: Colorfully Dyed Pandan Strips (Photo taken by the Author in Tandubas, Tawi-Tawi, in December 2020)

These bright-colored *pandan* strips intended for the front component of the *tepo* were white and dyeable in a hot coloring solution because of the low viscosity observed in their texture. However, those strips used for the rear *tepo* were resistant to the coloring solution due to their slimy surface. The coloring mixture was composed of an artificial coloring powder, *anjibi*, which was fully dissolved in scalding fresh water in a cooking pan over a lighted wooden stove. Miller et al. (2010) added that the shade of color obtained depends on the length of time the material is immersed in the hot coloring solution and the strength of the dye. For the mat weavers, white *pandan* strips were immersed and boiled in the coloring mixture for 20 min to get the desired color of the strip. The coloring solution could be used in dyeing white *pandan* strips only once due to the decreased amount of solute and evaporation of the solvent. Nevertheless, the mat weaver could still use its liquid remnants and precipitate but merely for enhancing or modifying other coloring solutions. For instance, a used yellow coloring solution, if added to a pink one, would yield darker pink after the new mixture was reheated to boiling. The mat weaver could also mix colors to explore and produce new pigment for the white *pandan* strips. For example, yellow pigment was combined with red pigment in boiling water, creating an orange pigment. These dyeing techniques and ideas of the Sama are supported by Miller et al. (2010). Meanwhile, the wet-colored *pandan* strips were not exposed by the mat weaver to sunlight for drying because the scorching heat of the sun would compromise the color intensity of the strips. According to them, it could turn the color of *pandan* strips light and pale.

Conclusion

The ideas of ethnoscience, ethnotechnology, ethnoengineering, and ethnomathematics (ethnoSTEM) found in Sama weaving of *tepo*, a hand-woven mat made from indigenously processed leaves of screw pine *(Pandanus tectorius)*, are loaded with scientific affluence. These should be preserved to preclude them from fading to oblivion in the coming generations. The ethno-engineering ideas in mat weaving involving structures of certain equipment (e.g., *pandan* presser) and intricate design of the mat depict their cultural and indigenous know-how and the weaver's natural endowment and creativity. Regarding ethnotechnology in mat weaving, hand and miscellaneous tools can be classified as cutting and fastening materials. Given their affordability and feasibility, early tools (e.g., traditional stoves) are still favored and used. Despite the technical evolution of certain hand equipment (e.g., *pandan* slitter) into machine or power tools, preference is given to the former as it embodies Sama cultural values and feasibility.

It should be noted that the mat weaver herself serves as the main instrument in creating mats along with their designs. Further, ethnoscience in mat weaving reveals ideas and concepts studied in botany, chemistry, and mechanical physics. These beliefs are so far consistent with scientific facts and principles. Finally, ethnomathematics concepts in mat weaving can be categorized into four domains: measurement, arithmetic, algebra, and geometry. These concepts, along with the skills and processes involved, are evident in basic education mathematics (DepEd, 2016, 2020) and tertiary-level or advanced mathematics (e.g., sinusoidal modeling).

In education, these ethnoSTEM concepts and ideas could be interleaved with competencies in basic education science, technology, engineering, and mathematics (STEM) subjects. Thus, mathematics teachers, especially in coastal communities, are urged to incorporate mathematics ideas of mat weaving to teach basic mathematics, equations, variation, function, and geometry. Likewise, science teachers are encouraged to utilize science concepts and ideas from the foregoing cultural knowledge system and practice (CKSP) in teaching biology, chemistry, physics, and earth science. In this way, learners could find STEM to be meaningful and realistic. Hence, educational stakeholders must support and embrace ethnoSTEM as an avenue to advance a more inclusive education for all. Ingilan and Jubilado (2021) underscored the urgent need for the Philippine Department of Education to champion culturally sensitive learning opportunities and materials for Filipinos, including the Sama ethnolinguistic group. Further, ethnoSTEM as an emerging topic or field of study should be explored in the context of other CKSPs and settings. Moreover, the results of this study could serve as a groundwork for the inclusion of other relevant ethno-knowledge approaches, such as ethno-arts, for future research.

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Conflict of Interest Statement

We have no conflict of interest to disclose.

AI Disclosure

We declare that this manuscript was prepared without the assistance of artificial intelligence. Hence, the content of this paper is original.

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