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Batik Mangrove Kutawaru: Scientific Knowledge and its Potential for Empowering Spatial Thinking Skills

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Abstract

The influence of globalization and modernization has made the condition of local wisdom in Indonesia very concerning. Preserving local wisdom can be through education, one of which is science learning. In addition, the basic skill that students must have to achieve 21st-century skills is spatial thinking skills. The research aims to identify scientific knowledge in the process of making batik mangrove as local wisdom in Kutawaru, Cilacap and analyze the potential of scientific knowledge in the process of making batik mangrove Kutawaru to empower spatial thinking skills. This research is a qualitative research, by using purposive sampling techniques. Data was collected using interviews, observation, and documentation. Data validity was tested using the triangulation technique. Data analysis for this research was conducted interactively through the stages of data collection, data reduction, data presentation, and drawing conclusion. This study contributes to ethnoscience by identifying the transformation of local knowledge in the production of batik mangrove Kutawaru into scientific knowledge that can improve spatial thinking skills in science learning.

How to Cite

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INTRODUCTION

Indonesia is a multicultural country with a diverse range of cultures (Salim & Aprison, 2024; Sumartias et al., 2020). Various forms of local knowledge have emerged from interactions between local communities and their surrounding environments (Fakhruddin, 2024). One effort to preserve local wisdom is through education, which is interconnected (Effendi, 2019), thereby shaping individuals who are knowledgeable, have strong character, and are able to adapt to change (Septarinjani et al., 2025). In the Merdeka Curriculum, local wisdom is one of the important themes in learning. Based on Permendikbud No. 79 of 2014, local wisdom is a subject of study or subject in educational units that contains learning content and processes about local potential and uniqueness intended to shape students understanding of the advantages and wisdom in the area where they live (Kementerian Pendidikan dan Kebudayaan, 2014). This is also supported by Minister of Education, Culture, Research, and Technology Decree No. 56/M/2022 concerning guidelines for curriculum implementation in the context of learning recovery and development, which states that preserving local wisdom is one of main themes in learning (Kementerian Pendidikan Kebudayaan Riset dan Teknologi, 2022).

Science education is one way to integrate local wisdom into learning (Damayanti et al., 2017; Homsombat, 2025). This allows students to learn science concepts through real phenomena in their surroundings, making learning more meaningful and contextual (Sahil et al., 2021). Teachers as facilitators also play an important role as a determining factor in the successful integration of local wisdom into science education (Zahro & Maulida, 2023). Teachers need to master three things: involvement in the learning process, imagination, and harmony (Mhakure & Mushaikwa, 2014). As science and technology advance, students need to equip themselves with basic skills to achieve competence, one of which is spatial thinking skills. This ability plays an important role in helping students visualize objects and create imaginary images of objects in their minds (Mathewson, 1999).

Local wisdom plays a vital role in preserving local cultural identity (Pesurnay, 2018). Batik mangrove Kutawaru is one of the local wisdom that has developed in Cilacap Regency (Khasanah et al., 2020). This batik was inspired by the local community's experience of living alongside various types of mangroves. Local communities with knowledge of the types of mangroves that contain color began to develop natural batik dyes from mangroves (Sollihah & Hum, 2024). There are various types of mangroves that can be used as natural dyes, including tingi and tancang (Wibowo et al., 2023). This practice demonstrates that knowledge originating from the indigenous knowledge of the Kutawaru community can be transformed into scientific knowledge that can be applied in learning (Martuti et al., 2017).

However, the reality is that the state of local wisdom in Indonesia is very concerning (Sarumaha et al., 2024). The tide of globalization and modernization has resulted in a shift in values and patterns in life (Nahak, 2019). Much local wisdom is now being abandoned and threatened with degradation from the social order (Siregar et al., 2024). This also happened to batik mangrove Kutawaru, which began to lose popularity, especially after the pandemic (Saragih et al., 2023). The integration of local wisdom into education has not been maximized and remains limited (Istiqomah et al., 2023; Ramlah et al., 2025). The learning process in schools is still dominated by the use of general learning resources, making it less relevant to students' lives (Ayushandra & Wuryastuti, 2022; Risamasu et al., 2023). Non-formal scientific knowledge from local knowledge, separated from the content of science learning because its truth is considered illusory (Mungmachon, 2012; Novitasari et al., 2017; Rikizaputra et al., 2022). Science teachers also lack in-depth knowledge of local wisdom and do not yet know how to integrate it into their teaching (Sarini & Selamet, 2019). This can impact students' spatial thinking abilities (Hanum, 2022), where activities such as observing, imagining, conceptualizing, understanding, or analyzing a local object are still limited (Apriyanto et al., 2024; Sari Nst et al., 2023). As a result, students will find it difficult to construct basic conceptual maps to help them develop reasoning and problem-solving skills (Sya'bani et al., 2023).

In previous research conducted by Martuti et al. (2017) and Khasanah et al. (2020), the potential of batik mangrove Kutawaru was examined from the perspective of creative economic products and artistic aspects in the utilization of mangrove plants as a source of natural dyes. In addition, research conducted by Fionita & Wulandari (2024) and Regina & Wijayaningputri (2022) has examined the integration of local wisdom in science learning as a source of contextual learning. However, these studies have generally not specifically identified the scientific knowledge contained in each stage of the batik mangrove Kutawaru-making process. Previous research have focused more on identifying scientific concepts in batik in general, without examining its potential relevance to specific cognitive abilities, particularly spatial thinking skills. In fact, the process of making batik mangrove, which involves the stages of motif creation, pattern batik, and dyeing, has the potential to train the ability of imagining, conceptualizing, problem-solving, and patterns seeking, which are part of spatial thinking skills (Tversky, 1993). Therefore, this research aims to identify scientific knowledge in the process of making batik mangrove as local wisdom in Kutawaru, Cilacap and analyze the potential of scientific knowledge in the process of making batik amangrove Kutawaru to empower spatial thinking skills.

METHOD

This research was conducted using a qualitative approach to identify scientific knowledge in the process of making batik mangrove in Kutawaru Village, Cilacap Regency. It also analyzed scientific findings on the empowerment aspect of spatial thinking skills, such as: (1) imaging, the ability to mentally imagine shapes, objects, or patterns before they are physically realized; (2) conceptualizing, the ability to understanding the concept of the shape and space of an object based on spatial princip; (3) problem solving, the ability to solve problems related to pattern, form, or work process of an objects; and (4) pattern seeking, the ability to recognize, create, and develop patterns of relationships between objects. The sampling technique used in this research was purposive sampling with criteria are (1) active craftsmen directly involved in the Kutawaru mangrove batik-making process; (2) native to the Kutawaru community, Cilacap; and (3) having at least 3-5 years of experience in making batik mangrove. Data collection was carried out using interviews, observation, and documentation of 5 batik mangrove Kutawaru craftsmen. Data analysis was performed using the Miles & Huberman (1984) interactive analysis model, which includes data collection, data reduction, data presentation, and conclusion drawing. The data categorization matrix table is presented in the Table 1.

Table 1. Data Categorization Matrix

Themes	Coding	Category
Scientific knowledge in the preparation stages of making batik mangrove Kutawaru	Preparation a canting, stove, dye bath, and washing pot (PA)	The shape of the tools and its use in making batik
		Material properties of canting, dye bath, and washing pot
	Preparation a mori batik fabric, batik wax, and batik dye (PB)	The use of mori fabric and batik wax as the basic materials for batik
		The use of mangroves as a natural dye for batik
	Soaking the mori fabric before the batik process (PK)	Remove stains from fabric
Scientific knowledge in the processing stages of making batik mangrove Kutawaru	Batik pattern making-process (PM)	Drawing a mangroves motif on fabric (visualization of object shapes)
	Pattern batik process (PP)	The ingredients of batik wax
		The use of batik wax to outline the pattern
	Coloring (PW)	Processing mangroves into natural batik dyes
		Dipping fabric into a mangrove dye
Scientific knowledge in the finishing stages of making batik mangrove Kutawaru	Fixation (PG)	The use of alum, lime, and tunjung as color-fixing agents
		Dipping fabric into a color-fixing solution
	Decolorization process (PL)	The use of soda ash as a leaching agent
		Dipping fabric into a soda ash solution

RESULT AND DISCUSSION

Based on the results of research on the process of making batik mangrove Kutawaru contains local community knowledge that can be used as a learning resource in science education. Because the indigenous knowledge of local communities contains scientific values that have not yet been formalized (Risamasu et al., 2023). Through the transformation of local knowledge into scientific knowledge, it becomes easier for students to learn scientific concepts (Damayanti et al., 2017). This is conducted by identifying scientific knowledge in the local wisdom of the mangrove batik-making process, covering chemical, biological, and physical aspects (Sudarmin & Asyhar, 2012).

Identification Scientific Knowledge in the Process of Making Batik Mangrove

The process of making batik mangrove consists of three main stages, namely preparation, processing, and finishing stages. The preparation stage begins with the preparation of tools. Preparing the tools is the first activity carried out by the craftsmen to prepare and ensure that all batik equipment is in good condition, one of them is a canting, as stated by informant in Table 2.

Based on Table 2, it shows that copper is used on the front of the stamp and the head of the writing tool. Meanwhile, wood is used as the handle material because it is light and does not get hot in the hands, like in Figure 1.

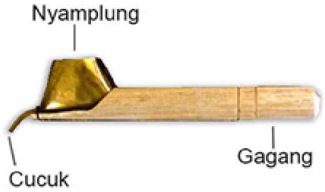

Figure 1. Characteristic of canting (Source: https://engrasia.com)

Scientifically, copper has good heat resistance, so the wax can remain liquid (Majanasastra, 2016). Copper acts as a conductor in the canting because it has good heat conductivity, the conductivity of copper is 385.0 W/m.K is able to maintain a stable nighttime temperature (Wardani et al., 2018). Copper's high boiling and melting points prevent the canting from easily expanding (Minneci et al., 2021). Meanwhile, wood is an insulator, making it suitable for use as a canting handle. This is because insulating materials are able to block heat, preventing it from being conducted effectively. Wood has a lower thermal conductivity than other insulating materials, at 0.17 W/m.K, which slows down heat transfer in wood (Muharom & Rifky, 2022) (physical aspect).

In addition, craftsmen also prepare the materials. The material preparation process is the initial stage carried out before starting the batik process, with the aim of preparing the materials that will be used for batik, one of them is a mangrove, as stated by informant in Table 3.

Based on Table 3 dan 4, it shows that one of the main ingredients that must be prepared is dye. Kutawaru batik artisans use mangrove trees as their natural dye. Mangrove plants such as tancang, tingi, or putut can be used to make dye, as they produce a lot of sap that produces red color. This knowledge was gained from his experience of living alongside various types of mangroves that thrive there, like in Figure 2.

Table 2. Direct Interview Quote with Informant TB

Initial	Interview Dialogue
AN:	"What material is this canting made of, ma'am?"
TB:	"The canting is made of copper, while the handle is made of wood." (PA/Informant/TB/7)
AN:	"If we were to replace it with another material, like iron or something, would that work?"
TB:	"No. Because if you use that, the canting will swell, and the batik pattern will get ruined." (PA/Informant/TB/8[WU)

Table 3. Direct Interview Quote with Informant TB

Initial	Interview Dialogue
AN:	"What are the dyes made from, Ma'am?"
TB:	"In here, the dyes made from mangroves, because there are so many mangroves around here, so there are used to make batik dyes. " (PB/Informant/TB/25)
AN:	"Is there only one type of mangrove used, or are there others, ma'am?"
TB:	"We use many different types of mangroves, including tingi, tancang, putut. " (PB/Informant/TB/26)

Figure 2. The types of mangroves (Sources:https://puimangroveusu.id; https://www.researchgate.net; https://id.wikipedia.org)

Scientifically, mangrove trees can thrive in Kutawaru because the area is located at the meeting point of seawater and freshwater, making it a habitat for mangrove forest ecosystems (Fauziyah et al., 2024). There are various species that thrive here, including: mangrove species, *Rhizophora apiculata, Avicennia marina, Avicennia alba, Soneratia caseolaris, Soneratia alba, Bruguiera cylindrical, Bruguiera gymnorhiza, Aegiceras corniculatum, Ceriops tagal, Ceriops decandra, Nypa fruticans*, and so on. All of these mangrove species belong to three families, namely: Avicenniaceae, Rhizophoraceae, and Sonneratiaceae (biological aspect). There are several species of mangroves used by craftsmen to make natural dyes, namely: (1) *Rhizophora mucronata* (tancang); (2) *Ceriops tagal* (tingi); (3) *Bruguiera gymnorhiza* (putut).

Morphologically, the species *Rhizophora mucronata* consists of the following organs: (1) prop roots and pneumatophores; (2) elliptical to oblong leaves with pointed tips and spines; (3) flowers located in the leaf axils and yellow in color; (4) brown fruit; and (5) a trunk, which is 20-30 meters tall with blackish brown in color. Meanwhile, the species *Bruguiera gymnorhiza* consists of the following organs: (1) the trunk is 5-20 meters tall, with grayish-white bark; (2) sturdy prop roots that support the plant; (3) leaves clustered at the ends of branches; (4) bell-shaped flowers that are pink in color; (5) fruit called hypocotyls that are cigar-shaped (Indriyaty et al., 2024) (biological aspect). Mangrove plants contain tannins that produce reddish-brown dyes (Verenkar & Krishnan, 2017) and flavonoids that produce yellow, cream, and light brown dyes. After that, the next step is soaking the mori fabric, as stated by informant in Table 5. There are also statements from another informant describing the types of fabric used in making batik mangrove, as stated by another informant in Table 6.

Based on Table 5 and 6, it shows that the soaking of mori fabric is adjusted according to the type of fabric. At the Kutawaru mangrove batik workshop, the fabric used is already mature, as it is considered more efficient and suitable for natural dyes, because primissima mori fabric is smooth and clean (no starch residue). This shortens the time needed to make mangrove batik, which is already quite time-consuming, as presented in Figure 3.

Figure 3. Soaking the mori fabric (Sources: Permatasari & Lestari, 2023)

Table 5. Direct Interview Quote with Informant TB

Initial	Interview Dialogue
AN:	"Can the fabric be ready to used for batik, ma'am?"
TB:	"This is ready to use." (PK/Informant/TB/29)
AN:	"So there is no need to soak or pre-treat it, ma'am?"
TB:	"No, because here we use fabric that has been pre-treated or processed. But, there is also untreated fabric, which needs to be pre-treated first to remove the starch residue." (PK/Informant/TB/30)

Table 6. Direct Interview Quote with Informant RT

Initial	Interview Dialogue
AN:	"Does this fabric need to be pre-treated, ma'am?"
RT:	"Oh, no. This fabric has already been pre-treated, so it's ready to use for batik." (PK/Informant/RT/30)
AN:	"It's already been processed – what does that mean, ma'am?"
RT:	"Is ready to be used for batik, because already clean and smooth from the factory." (PK/Informant/RT/31)

Scientifically, raw fabric needs to undergo a fabric maturation or mordanting process. The mordanting process is carried out to remove any remaining starch and dirt that is still attached to the fabric, which is done by: (1) before mordanting, the mori fabric is soaked in a wetting solution or TRO (Turkish Red Oil). TRO is a hydrophilic substance produced from a chemical reaction between castor oil and sulfuric acid (H_2SO_4) (chemical aspect). (2) alum as a mordanting agent is dissolved in water. Alum or potassium aluminum sulfate ($KAl(SO_4)_2.1_2H_2O$) is an ionic compound that is easily soluble in water. (3) mori fabric that has been soaked in TRO solution is placed in alum solution, then heated. The fibers of mori fabric, which are composed of cellulose (a natural polymer with many -OH groups), will bond with Al^{3+} ions in the alum solution. Al^{3+} ions can diffuse into fabric fibers and form a mordant bridge between the fabric fibers and alum solution, allowing fabric fibers to open up and maximize the subsequent process (dyeing). Meanwhile, the heating process is carried out to increase the kinetic energy. (4) the mori fabric is soaked overnight in a alum solution to maximize the strength of fabric when used in dyeing, dried under the sun to accelerate the evaporation of water content in the fabric. This is because the heat of the sun can increase the kinetic energy of water molecules, and water molecules can change from liquid to gas (water vapor) (Nuriana, 2021) (chemical aspect).

Meanwhile, in production of Kutawaru mangrove batik, matured or mordanted fabric is used. The mori fabric used is primissima mori fabric, which has a thread number of Tex 10.2-9.0 (SNI 08-0280-2004) made from cotton yarn (cotton fiber), giving it a smooth surface. This fabric has following characteristics and properties: right weight (not too thick or thin), so that absorption of dye into fabric fibers can be maximized. This is because the density of the yarn affects the fabric's absorbency of dye. Fabric with a high density will absorb more dye, because tightly packed yarns are able to bind more color (Rumiyati et al., 2022) (biological aspect). The next stage in mangrove batik-making process is processing, which includes creating batik motifs, applying patterns, and dyeing. This stage begins with creating batik patterns, as stated by informant in Table 7.

Based on Table 7, it shows that about motif creation includes: (1) the motif creation process is carried out by first designing the motif on paper and measuring the fabric so that when the motif is applied to fabric, it fits perfectly; (2) batik motifs are inspired by animals and plants found in the surrounding environment, with the addition of supporting elements such as rocks. The plants and animals used are inspired by the surrounding mangrove forest, such as various types of mangrove trees, mangrove crabs, bogo fish, and so on; and (3) the process of drawing motifs is done in two ways, namely by drawing the entire plant or only part of plant, such as roots, trunk, or fruit, one example is nipah palm shown in the Figure 4.

Figure 4. The parts of nipah (*Nypa fruticans*) (Source: https://rri.co.id)

Scientifically, the process of creating motifs begins with measuring fabric to be used. The mori fabric used is measured using a measuring tape or ruler, generally measuring 2.25-2.5 meters in length and 1.05 meters in width (Nurdin, 2021) (physical aspect). Then, for objects used in the Kutawaru mangrove batik motif, there are biotic and abiotic components found in mangrove forest ecosystem. The biotic components of the mangrove forest ecosystem include: various species of mangrove plants, tali pitingan plants, mud crabs (*Scylla serrata*), mudskippers (*Periophthalmus* sp.), wijayakusuma flowers (*Epiphyllum anguliger*), and so on. Meanwhile, the abiotic components in mangrove forest ecosystem are everything that is not alive in mangrove ecosystem, such as rocks and water (Suryono, 2015).

Table 7. Direct Interview Quote with Informant RT

Initial	Interview Dialogue
AN:	"How do you make the batik pattern, ma'am?"
RT:	"First, draw pattern on paper, then trace it onto fabric and adjust it to fit." (PM/Informant/RT/34)
AN:	"Where did you get the inspiration for the design, ma'am?"
RT:	"It's inspired by the local area, so there are many types of mangroves, brackish-water animals, and plants that symbolize this region." (PM/Informant/RT/40)
AN:	"How can you turn an object into a motifs?"
RT:	"Scaled to size. There are objects where all parts are drawn, but others are drawn only in some parts." (PM/Informant/RT/42)

After the batik motif creation process, the next process is the pattern batik process. There are several steps involved in this stage, as stated by informant in Table 8. It shows that pattern batik making is as follows: (1) heat the wax to be used for batik until it melts. Once melted, the wax is collected in a nyamplung canting; (2) to apply the wax, the canting containing the wax is blown on first so that it is not too hot or too cold, as this affects the shape of the motif; and (3) the wax is made from a mixture of various ingredients and serves to cover or block the parts of the fabric that are not to be dyed.

Scientifically, the process of applying batik patterns begins by heating wax in a pan on the stove. When the stove is turned on, heat transfer occurs through conduction, convection, and radiation from the heat of the flame, just like when heating water. Solid night wax is heated on a stove at a temperature of ±60-80°C, which generally melts at a temperature of 67°C. Conduction heat transfer occurs when heat from the stove flame is transferred to the pan (metal), so that the night wax is also exposed to heat from the pan. As a result, the wax undergoes a change in state from solid to liquid (melting) because it receives heat from the stove. In this process, heat energy slowly diffuses from a higher temperature point to a lower temperature point, without passing through an intermediary and without the transfer of constituent particles. Then, convective heat transfer occurs when heat from the stove flame is carried by air flow, causing the temperature around the wax to rise and melt, resulting in the movement of the transmission medium. Meanwhile, radiative heat transfer occurs when heat from the flame radiates directly to the pan without an intermediary (As Syukri et al., 2023) (physical aspect).

When the wax has melted, it is collected in the canting container and then dispensed through the canting nozzle, paying attention to the thickness. The canting nozzle is shaped like a small pipe as an outlet for the wax liquid, with a diameter of ±1-3 mm. The wax fluid flowing through the small pipe will experience friction between the contact surface (pipe surface) and the object (wax liquid). Under these conditions, the continuity equation applies, which explains the law of conservation of mass, stating that the amount of mass flowing through various cross-sections per unit time is always the same, thus formulated as: $Q_1 = Q_2$ or $A_1V_1 = A_2V_2$, where Q is the flow rate (m^3/s); A is the cross-sectional area of the pipe (m^2), and v is the flow velocity (m/s) (Sulistiani et al., 2022) (physical aspect).

Night candles function as color barriers because, in principle, candles contain oil and dyes contain water, both of which have the same liquid properties but differ in molecular mass, making them incompatible. Water (H_2O) is a natural compound formed from the bonding of oxygen (O) and hydrogen (H) atoms, which is classified as a polar compound (having positive and negative charges). while oil is an organic hydrocarbon compound consisting of hydrogen (H) and carbon (C) atoms that is liquid in form, insoluble in water, and classified as a nonpolar compound (has no charge). This condition prevents batik dyes from seeping into the fabric, as they are blocked by the wax (Ardian & Safaruddin, 2022; Kusuma, 2019; Yunus, 2022) (chemical aspect).

The next step in the process of making batik mangrove is coloring, as stated by informant in Table 9. After sorting the mangrove raw materials, the next step in the dyeing process as stated by another informant in Table 10.

Table 8. Direct Interview Quote with Informant TB

Initial	Interview Dialogue
AN:	"After creating the pattern on the fabric, what's the next step, ma'am?"
TB:	"After that, the pattern is outlined using batik wax." (PP/Informant/TB/37)
AN:	"How do you apply batik wax to the pattern, ma'am?"
TB:	"First, the batik wax is heated until it melts, then poured into the nyamplung canting. Before applying it to the fabric, the wax is blown on to cool it down slightly, so it doesn't overflow." (PP/Informant/TB/41)
AN:	"What is that batik wax made of, ma'am? And what is it used for?"
TB:	"It's made from many ingredients, like tree sap, oil, and wax. It's use to cover the areas that aren't dyed, so that a pattern is formed." (PP/Informant/TB/43)

Table 9. Direct Interview Quotes with Informant DD

Initial	Interview Dialogue
AN:	"What kind of dye is used here, sir?"
DD:	"The dye used there is made from mangrove, in here we use tancang and tingi." (PW/Informant/DD/13)
AN:	"What are the criteria for choosing the mangrove, sir?"
DD:	"Choose mature mangrove (tancang), not young ones." (PW/Informant/DD/32)

Table 10. Direct Interview Quotes with Informant TB

Initial	Interview Dialogue
AN:	"For the first step of the dyeing process, what should I do first, ma'am?"
TB:	"First, process the mangroves into batik dye. Then, dip the fabric into the mangrove dye." (PW/Informant/TB/49)
AN:	"How do you process those mangroves?"
TB:	"First, the mangrove fruit must be chopped, then dried for 3-5 days until it turns reddish-brown. Boil the fruit for 2-3 hours until it turns thick. Next, let it cool, strain it, and transfer it to the dye vat." (PW/Informant/TB/50)
AN:	"How does the dyeing process work, ma'am?"
TB:	"The fabric is dipped in dye. It usually takes two people to pull the fabric back and forth. After that, the fabric is air-dried and must not be exposed to direct sunlight." (PW/Informant/TB/55)

Based on Table 9 and 10, it shows that dyeing is carried out by: (1) preparing tancang fruit as raw material for batik dye with the following criteria: old fruit that is dark in color and heavy, so that the resulting color is maximized; (2) dye production is carried out by cutting mangrove fruit into 2-3 cm pieces, drying them for 3-5 days until they are dry and reddish brown in color. Then, they are boiled for 2-3 hours until thickened; and (3) the dyeing process is carried out by dipping the fabric into a dye vat, as presented in Figure 5.

Figure 5. The process of making batik dyes

Scientifically, mature and dark-colored tancang fruit (*Rhizophora mucronata*) has an elongated spherical shape. When ripe, the fruit segments turn greenish-brown with a red cotyledon neck and easily detach from the fruit. This is because the fruit of the *Rhizophora mucronata* mangrove species belongs to the viviparous fruit type, meaning that the seeds begin to germinate while still attached to the parent tree, so that the sprouts emerge from the fruit (Mustika et al., 2014) (biological aspect). Next, the sorted fruit will be cut into 2-3 cm pieces. The smaller the mangrove fruit, the larger its surface area will be. The water content in mangroves will move to the surface as the mangrove fruit thickens. As a result, when dried in the sun, the entire surface area will dry faster, because mangrove fruit with high water content releases heat. The drying process takes approximately 3-5 days until the fruit turns reddish-brown (Saputra et al., 2023) (physical aspect).

Next, mangrove extraction is carried out by taking the chemical compounds from plant or animal tissue using a suitable solvent. Extraction is carried out by boiling the mangrove in water until it changes color and shrinks. This process aims to extract tannins and flavonoids from other mixtures. The mangrove extract is then left to settle overnight to facilitate decantation of the dye. This process occurs because mangrove particles are larger and denser than water (Paryanto et al., 2015; Putri et al., 2020) (chemical aspect). The dyeing process is carried out in a dyeing vat by dipping the fabric into the dye. The dye diffuses into the fabric fibers, which is when the molecules in the dye solution move from a high concentration to a lower concentration (fabric fibers). The fabric is dipped repeatedly, at least 10 times, until the dye is absorbed more evenly into the fabric (Okyranida et al., 2024) (physical aspect).

After the dyeing process, the next step is color locking or fixation, as stated by informant in Table 11. It shows that the color locking process is carried out by soaking batik fabric that has been dyed in a color locking agent. The color-fixing raw materials are mixed with water, left overnight until sediment forms, and then the water can be used. The color-fixing process is carried out by dipping the fabric into the color-fixing material, then draining it until the water content is sufficiently reduced. This process is repeated at least three times. After that, the fabric that has been color-fixed can be dried in the sun. The color locking agent is prepared by making a color locking agent, including alum, lime, or tunjung, as presented in Figure 6.

Figure 6. Characteristics of alum, lime, and tunjung
(Source: https://www.bahankain.com)

Scientifically, fixing agents consist of: (1) alum (Al_2SO_4), which keeps fabric color the same as its original color, due to a reaction between Al^{2+} ions in alum and tannin compounds in mangroves that do not produce complex salts; (2) lime ($CaCO_3$), which produces a color that is lighter than the original color; and (3) iron sulfate ($FeSO_4$), which produces a color that is darker than the original color. This occurs due to a chemical reaction between tannin in the natural dye and the Fe^{2+} ions in iron sulfate, forming stronger and more complex salt bonds, which produce a dark brown color. The process of making a fixative is done by dissolving solute (raw material: alum, lime, or iron sulfate) into solvent (water). Then, the solution is left overnight until a precipitate (heterogeneous mixture) forms, after which it can be used for fixation. Next, the color fixation process is carried out by repeatedly soaking the batik fabric that has been dipped in dye into fixation solution. This process is carried out so that diffusion of fixative ions into fabric fibers can proceed optimally, ensure color locking process is even (Pujilestari, 2014). After performing color locking process, next process is decolorization process, as stated by informant in Table 12.

Table 11. Direct Interview Quotes with Informant TB

Initial	Interview Dialogue
AN:	"Is the fabric fully processed after the dyeing stage, ma'am?"
TB:	"Not yet. The colors need to be set first. If they aren't set, the batik colors will bleed." (PG/Informant/TB/58)
AN:	"How do lock the color, ma'am?"
TB:	"It uses color-fixing agents. There are many types, but the ones commonly used here are alum, lime, and tunjung." (PG/Informant/TB/59)
AN:	"What do you do with the color-fixing agent so it can lock in the color, ma'am?"
TB:	"This color-locking agent is mixed with water and left to settle overnight. After that, the water can be used to lock in the color." (PG/Informant/TB/60)
AN:	"How do set the color on the fabric, ma'am?"
TB:	"It's almost the same as the dyeing process. The fabric is dipped into a fixing solution, then drained. This is repeated three times. (PG/Informant/TB/61)

Table 12. Direct Interview Quotes with Informant SL

Initial	Interview Dialogue
AN:	"After this, can the batik be used, sir?"
SL:	"Not yet. Because it hasn't been lorod yet." (PL/Informant/SL/50)
AN:	"What does nglorod mean, sir?"
SL:	"Nglorod is the process of dipping batik fabric into hot water mixed with soda ash." (PL/Informant/SL/51)
AN:	"What is the purpose of that, sir?"

Based on Table 12, it shows that: the wax removal process aims to remove the wax that is still attached to the batik fabric by repeatedly dipping the fabric in boiling water containing soda ash, as presented in Figure 7.

Figure 7. Decolorization process or nglorod

Scientifically, the boiling process is carried out by heating water until it boils. During the process of boiling water, heat is transferred by conduction and convection from the heat of the fire to the boiling pot, carried out at a temperature of 100°C until boiling (physical aspect). Then, dissolve 3 tablespoons of soda ash or soda ash with the chemical formula Na_2CO_3 (chemical aspect). Soda ash, or sodium carbonate, is a white powder that is dissolved to form a soda ash solution. Then, the fabric is dipped into the soda ash solution until the solution is absorbed into the fabric and the wax can be removed. Soda ash solution or sodium carbonate (Na_2CO_3) functions as a neutral sodium salt of carbonic acid, has the ability to absorb substances around it (hygroscopic), and produces a strong alkaline solution. The soda ash solution, which produces cohesive and adhesive forces, can accelerate the process of removing wax from the fabric. Cohesive forces occur when molecules in the soda ash solution attract each other. Wax and soda ash solution form a heterogeneous mixture due to the adhesive force between wax and water. The differences between the two molecules cause them to repel each other and form their own layers (chemical aspect). Fabric that has been treated can be dried in the sun until it is completely dry (Nurdin, 2021).

Analysis of Scientific Knowledge Potential in the Process of Making Batik Mangrove Kutawaru on Empowering Spatial Thinking Skills

Based on the results of scientific knowledge identification in batik mangrove Kutawaru-making process, it shows that there is scientific knowledge that potential to empower students' spatial thinking abilities, which consists of four aspects, namely: imaging, conceptualizing, problem solving, and pattern seeking (Tversky, 1993). The results of identification shown in Figure 1.

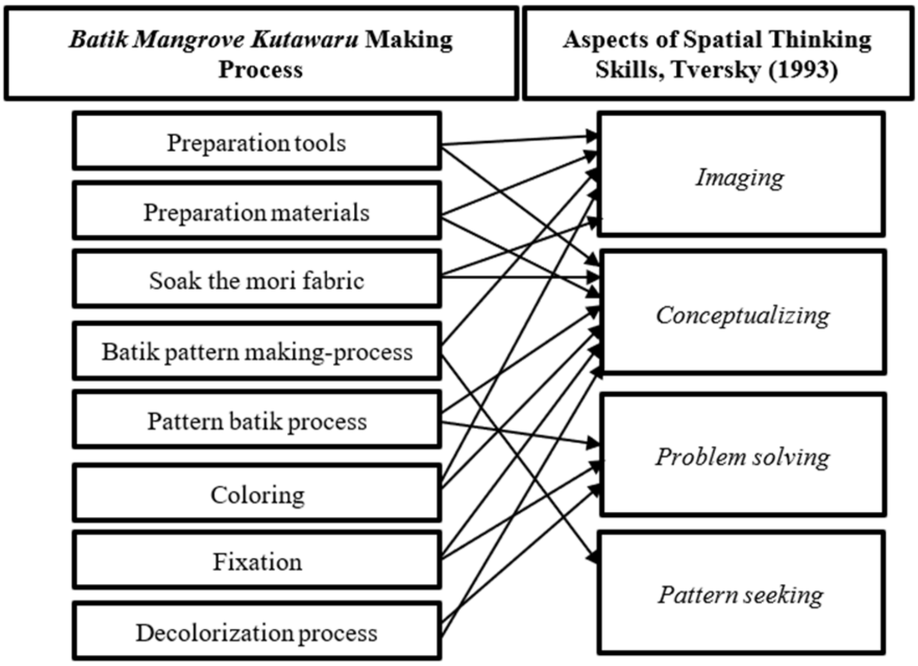

Figure 8. Chart of the Potential of the Batik Mangrove Kutawaru Making Process for Empowering Spatial Thinking Skills

The process of batik mangrove Kutawaru consists of three main stages, namely: the preparing stage, the processing stage, and the finishing stage, which have the potential to empower spatial thinking skills as described in detail below:

The Potential for Empowering Spatial Thinking Skills at the Preparing Stage

The process of preparing tools and materials has the potential to empower imaging and conceptualizing aspects. Scientific knowledge in the process of preparing tools, such as: canting, which contains copper as a conductor and wood as an insulator. In this case, students can empower the imaging aspect by imagining things related to the canting, such as: the copper content in the canting, the advantages of copper, and the application of conductors and insulators in the canting. In addition, it has the potential to empower the conceptualizing aspect, where students can understand the function of conductors and insulators in the canting. This is in line with the research by Saputri & Aryati (2024), which states that the batik bakaran ethnoscience module encourages students to imagine, identify, and understand.

Scientific knowledge in the process of preparing materials, such as in the use of mangrove plants as dyes, uses their imagination to visualize the biotic and abiotic components that make up the mangrove forest ecosystem and to imagine which mangrove species can be processed into batik dyes (imaging). In addition, students are able to understand the differences between each mangrove species and know the color characteristics produced by each organ of the mangrove plant. This is in line with the research by Regina & Wijayaningputri (2022), which states that exploring the biodiversity of mangrove ecosystems can enhance students' imagination and understanding.

The process of dyeing mori fabric has the potential to empower aspects of imaging and conceptualizing. Scientific knowledge contained in the process of dyeing mori fabric, such as: the density of cotton threads in cotton fibers affects the fabric's absorbency of dye. In this case, students empower the imaging aspect by imagining how cotton threads in mature fabric fibers can absorb dye more effectively. Furthermore, it has the potential to empower the conceptualizing aspect, as students can understand the relationship between mature fabric fibers and their ability to absorb liquids. This is in line with previous research that students can develop their imagination and conceptual abilities (Nuriana, 2021).

The Potential for Empowering Spatial Thinking Skills at the Processing Stage

The processing stage consists of the process of creating batik motifs, applying patterns, and dyeing. Scientific knowledge in the process of creating batik motifs has the potential to empower the aspects of imaging and pattern seeking. In this case, students can empower the aspect of imaging by imagining the characteristics and structure of biotic and abiotic components in mangrove ecosystems. They can also empower the aspect of pattern seeking by recognizing the appropriate motif patterns in the interaction between biotic and abiotic components of mangrove ecosystems.

Scientific knowledge in the batik pattern process has the potential to empower conceptualizing and problem-solving aspects. In this case, students can empower the conceptualizing aspect by being able to understand how temperature can affect the viscosity of wax and understand how wax can prevent fabric from absorbing dye. They can also empower the problem-solving aspect by training students to adjust the temperature of the wax so that the flow is stable. This is in line with the research by Mujtahidin & Amelia (2022), which states that batik printing fosters understanding and problem-solving aspects.

Scientific knowledge of the coloring process has the potential to empower the aspects of imaging and conceptualizing. In this case, students can empower the imaging aspect by imagining how mangrove fruit criteria can be used as dyes. They can also empower the conceptualizing aspect by understanding the relationship between dye solutions, fabric fibers, and beeswax. This is in line with previous research, which found that the process of searching for raw materials for dye production can stimulate students' imagination (Regina & Wijayaningputri, 2022).

The Potential for Empowering Spatial Thinking Skills at the Finishing Stage

The finishing stage consists of color fixing and bleaching processes. Scientific knowledge of color fixing and bleaching processes has the potential to empower conceptualizing and problem solving aspects. In this case, students can empower the conceptualizing aspect by understanding the relationship between the fixative and the fabric fibers. They can also empower the problem-solving aspect by training students to solve problems if the color fixing process is not optimal. This is in line with research of Nuriana (2021), which states that choosing a fixative and understanding its color characteristics can foster the conceptualizing and problem-solving aspects.

CONCLUSION

Based on the results of scientific knowledge identification in the process of making batik mangrove Kutawaru, each stage contains local knowledge that can present the application of science concepts. Furthermore, scientific knowledge gained from identifying the batik mangrove Kutawaru-making process has the potential to holistically empower spatial thinking skills. Each stage involves activities of visualization or imagination, conceptualization, problem solving, or pattern recognition, which are integrated and continuous. Thus, the identification of scientific knowledge in the mangrove batik-making process serves as an effective contextual learning platform to empower students' spatial thinking skills. A limitation of this study is that it has not directly tested the application of these findings in science education in the classroom. This could serve as a reference for other researchers to conduct further studies.

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