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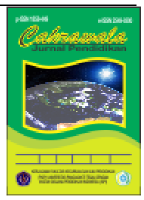

The Potential of Scientific Knowledge of *Jamu Gendong* Production as Science Learning Enrichment Source

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Abstract

The imbalance between the demands of 21st-century globalization and students' higher-order thinking skills, along with the limited availability of learning media integrating local wisdom, has caused science learning to be less contextual and meaningful. This research aimed to identify scientific knowledge embedded in the traditional production process of jamu gendong as a form of local wisdom. The study employed a qualitative method using an ethnographic approach, involving five jamu gendong producers as primary respondents and six science teachers as informants. Data were collected through participant observation, in-depth interviews, and documentation, and were analyzed using interactive analysis techniques. The findings revealed that the jamu gendong production process contained scientific concepts related to biology, physics, and chemistry. These results indicated that reconstructed local knowledge could function as a contextual science learning resource that supported students' understanding of scientific concepts, fostered higher-order thinking skills, and strengthened cultural appreciation.

Keywords: *science education, local wisdom, ethnoscience, jamu gendong*

INTRODUCTION

The globalization of the 21st century has reached the era of 5.0, where technology has advanced rapidly, influencing all aspects of human life and becoming an essential part of human needs (Nastiti & 'Abdu, 2020). In this context, education serves as one of the main pathways to improving a nation's welfare. Teachers and students are required to adapt to the rapid pace of globalization through learning that promotes skills, competence, and lifelong learning. Mastery of 21st-century skills which include communication, collaboration, critical thinking and problem solving, and creativity and innovation is essential for students' success in education and their future careers (Mardhiyah et al., 2021). Therefore, mastery of these 21st-century skills must be strengthened from its foundation.

According to Presseisen & Barbara (1984), indicators of basic thinking skills consist of *cause and effect*, *transformation*, *relationship/correlation*, *classification*, and *qualification*, all of which can stimulate higher-order thinking skills. This is supported by research by Hayati & Setiawan (2022), who state that the ability to explain causal relationships is an essential component of

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critical thinking in 21st-century skills. Ridwan (2021) asserts that one of the basic thinking indicators integrating or connecting prior and new knowledge (*transformation*) can create meaningful learning and increase critical thinking ability by 32%. Apriana et al. (2024) emphasize that pattern recognition, which is part of *relationship/correlation* in basic thinking, is also a key indicator in computational thinking that fosters critical reasoning. Classification is a skill in observation activities, where students learn the process of identifying, understanding, and grouping objects or data based on observed attributes. This process is part of the development of computational thinking skills, which are essential for problem solving in PBL (Abdelkader et al., 2024). A study by Astra et al. (2023) showed that students' critical thinking skills increased progressively over three cycles, with the average score increasing from 55% to 83%. According to Wahib (2021), quality assessment is carried out through an evaluation process. Evaluation skills help students recognize arguments, distinguish between fact and opinion, and verify evidence. This process is essential for analytical reasoning, as it requires a deep understanding of evidence and the ability to question underlying assumptions and motives (Hakkinen et al., 2025). Therefore, strengthening basic thinking skills is essential as a foundation for critical thinking.

However, in practice, strengthening basic thinking skills to improve higher-order thinking through science learning still faces several challenges. Research by Zairina & Hidayati (2022) found low argumentative writing skills among students, with an average percentage of 57.33%. Furthermore, the integration of local wisdom in science learning has not been maximized, even though it is emphasized in policies such as the Ministerial Decree of Education, Culture, Research, and Technology No. 56 of 2022 on Curriculum Implementation Guidelines and Regulation No. 35 of 2018. In addition, classroom learning remains largely rote-based, less contextual, and rarely connects scientific concepts with local culture, making it difficult for students to see the relevance of science in daily life and their cultural identity Firda et al. (2023). Moreover, the lack of culturally-based learning materials and media remains a significant barrier. Many teachers struggle to design teaching materials, modules, or ethnoscience-based media due to limited training, lack of model examples, and insufficient facilities and resources Dole et al. (2020). These conditions cause local knowledge, such as *jamu gendong*, to be increasingly underexplored in science education. Consequently, not only are students' basic thinking skills underdeveloped, but local wisdom itself also risks being forgotten by younger generations.

One form of local wisdom that continues to endure amid modernization is *jamu gendong*, a traditional herbal drink that has long been part of Javanese culture (Witasari et al., 2025). *Jamu gendong* not only represents cultural identity and the values of local wisdom but also holds significant scientific potential within its production process. From the selection of natural ingredients rich in bioactive compounds, the mixing and boiling techniques that involve chemical principles, to the packaging methods connected to biological and physical concepts, the entire *jamu gendong* production process reflects scientific knowledge passed down through generations. Thus, *jamu gendong* as an indigenous knowledge should not only be understood as a cultural product but also as a contextual and relevant learning resource that can enrich science education due to the potential of scientific knowledge of it's making process (Listiyani et al., 2025).

Previous studies have shown that local wisdom has great potential to be reconstructed into scientific knowledge and utilized in science learning. Sudarmin & Asyhar (2012) revealed the transformation of the traditional knowledge of the Cilacap community regarding *jamu* production into scientific knowledge, although their study mainly focused on ingredients, general descriptions of the preparation process, as well as the benefits and uses of *jamu* as a learning resource. Putri et al. (2022) also examined traditional herbal formulations of the Keraton Sumenep community through an ethnoscience approach and showed that *jamu* can be reconstructed into lower-secondary science concepts, such as heterogeneous mixtures, the drying process related to heat, and the use of natural ingredients without additives. Although both studies emphasize the potential of *jamu* as a contextual learning resource, previous studies have not produced structured teaching materials nor linked them to strengthening of basic thinking skills as the foundation of higher-order thinking. Therefore, this study offers novelty through the identification of scientific knowledge within the *jamu gendong* production process and its potential to enhance basic thinking skills, which is packaged in the form of a booklet.

This study aims to identify and reconstruct the scientific knowledge embedded in the *jamu gendong* production process as a local wisdom of Nguter, Sukoharjo, and to analyze its potential in empowering basic thinking skills presented in the form of a local-wisdom-based science booklet as enrichment material for science learning. Specifically, this study connects the stages of *jamu* preparation with relevant basic science concepts to strengthen students' foundational thinking abilities. Theoretically, this study expands ethnoscience research within the context of *jamu gendong*, which has not yet been widely explored, while practically producing contextual teaching materials that are easy to integrate into classroom instruction.

METHODS

This study employed a qualitative research design with an ethnographic approach to gain a deep understanding of the scientific phenomena embedded within the cultural and social context of traditional *jamu gendong* production (Fahrozy et al., 2022). The research was conducted at the center of *jamu gendong* production in Nguter Village, Sukoharjo Regency, Central Java. The entire research process, from preparation and data collection to analysis, was carried out between October 2023 and December 2024. The ethnographic approach was chosen to facilitate the reconstruction of scientific knowledge from local practices through detailed data collection via direct observation and in-depth interviews (Arnout et al., 2020; Siahaan et al., 2021).

The research subjects were selected using purposive sampling, a technique where informants are chosen based on specific criteria to ensure they can provide rich and relevant information to answer the research questions (Kusumastuti & Khoiron, 2019). The primary informants were three *jamu gendong* producers who met the following criteria: 1) they were authentic, traditional producers of *jamu gendong*; 2) they were domiciled in the Nguter sub-district; and 3) they were still actively producing and selling their products. This initial sample was expanded using the snowball sampling technique, where existing informants recommended other producers who fit the research criteria (Nurdiani, 2014). For preliminary data collection to understand the educational context, the sample also included six science teachers and eighteen junior high school students from three schools in the Nguter sub-district (SMPN 1, SMPN 2, and SMPN 3 Nguter).

Data were collected using a combination of participant observation, in-depth interviews, and documentation. Participant observation was conducted by directly observing the entire process of *jamu gendong* production, from ingredient preparation to the final product. The researcher used an observation sheet to systematically record the steps, techniques, and any observable scientific aspects. In-depth interviews were conducted with the *jamu gendong* producers to

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explore their traditional knowledge regarding the production process. Semi-structured interviews were also held with science teachers and students to gather information on the existing integration of local wisdom in science learning. The documentation process involved collecting supporting data such as photographs, audio/video recordings of the production process, and relevant scientific literature from books and journal articles (Kusumastuti & Khoiron, 2019).

To ensure the credibility and validity of the findings, the data were subjected to triangulation and peer debriefing. Source triangulation was performed by cross-verifying the data collected from observations, interviews, and documentation to obtain consistent and comprehensive findings (Abdussamad, 2021). Peer debriefing involved discussions with academic colleagues competent in the research field to review the findings, confirm interpretations, and minimize researcher bias, thereby enhancing the objectivity of the results. The data analysis technique was guided by the interactive model of Miles & Huberman (1994), which includes three concurrent flows of activity: data reduction, data display, and conclusion drawing/verification. Initially, all collected data were transcribed and organized. In the data reduction stage, the data were summarized, coded, and organized by selecting key information and identifying emerging themes and patterns. Following this, the processed information was presented in the data display stage through narrative text and flowcharts to provide a clear and structured overview of the findings. Finally, conclusions were drawn from the displayed data. This process was iterative, with initial conclusions being continuously verified and refined against the data until they were deemed credible and well-supported by the evidence.

RESULTS AND DISCUSSION

The research findings indicate that each stage of the *jamu gendong* production process in Nguter, Sukoharjo, contains a wealth of scientific knowledge spanning biology, chemistry, and physics. This local knowledge, traditionally passed down through practice, can be systematically deconstructed and aligned with formal scientific concepts taught in schools. These findings align with previous research by Sudarmin and Asyhar (2012), who also concluded that traditional *jamu*-making processes are rich in scientific concepts suitable for educational reconstruction.

Scientific Knowledge in *Jamu Gendong* Production

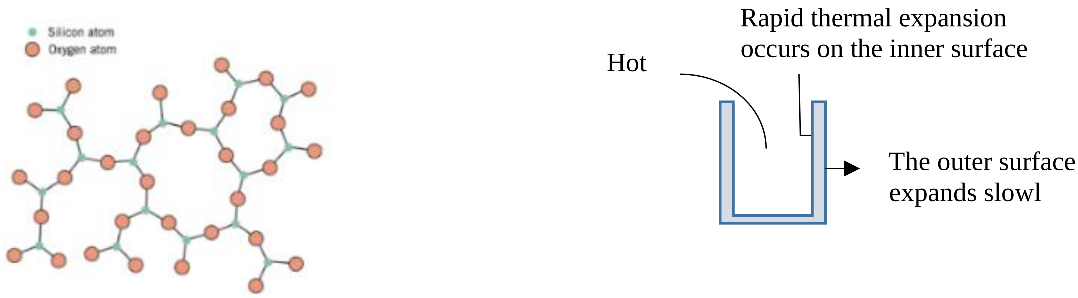
The production process of *jamu gendong* is systematically divided into three main stages: a) the preparation stage, consisting of preparing tools and materials, roasting, also tools and materials sanitation; b) the making stage, consisting of cutting, washing, grinding, formulating, boiling, squeezing and filtering; c) the packaging stage, consisting of pouring *jamu* into bottles and pouring hot water (*pengecoran*). The detailed identification of scientific knowledge on the stage of preparation is presented in Table 1.

Table 1. Identification of Scientific Knowledge on The Stage of Preparation

Process	Local Knowledge	Scientific Knowledge
Boiling new glass bottles	Glass bottles are boiled in a saucepan before first use to reduces the risk of breakage due to temperature changes.	The process of boiling causes the molecules in the glass to gain energy and experience structural relaxation so that it can prevent breaking due to thermal stress (chemical and physical aspects).
sanitizing glass bottles	Glass bottles are washed by adding a mixture of soap and gravel to the bottle and shaking it. This makes it easier to clean hard-to-reach areas. Then, they are rinsed	A shaken mixture of gravel and soap can cause friction and turbulence which helps erode stuck dirt (**physics aspect**). Dish washing soap contains surfactants which are able to emulsify oil, kill bacteria and dissolve organic dirt (**chemical and biological aspects**).

	under running tap water until no suds remain. A second rinse is performed using hot water for added sterility, thus maintaining the glass bottle's cleanliness and reducing bacterial contamination.	When rinsing the two glass bottles using hot water it is able to dissolve the chemical residue on the glass more effectively, speed up the hydrolysis reaction, and effectively kill bacteria (**chemical and biological aspects**). Rinsing with hot water can reduce the risk of the bottle breaking when pouring herbs and hot water into it (**physics aspect**). Washing that is not clean enough can lead bottles becoming crusty and easy for bacteria to grow (**biological aspect**).
Roasting	The roasting process makes fennel, cipir, and dawung easier to grind and preserves them longer. Furthermore, roasting reduces the characteristic bitterness of ginger and allows it to mature more thoroughly.	The heat from the pan causes the water in the roasted ingredients to evaporate, dehydrating them. Continued heat breaks down the cell structure, resulting in changes in texture, flavor, and aroma (**physics and chemistry aspects**). Heat activates the aldol reaction in ginger, which reduces its bitterness (**chemistry aspect**). The aromas emitted from the herbs and spices are detectable by the nose (**biological aspect**).

Table 1 highlights that the boiling of glass bottles reflects a simplified form of annealing, in which gradual heating and slow cooling allow structural relaxation that reduces internal thermal stress (**physics aspect**) (Narayanaswamy, 1986). Glass, composed primarily of silica (SiO_2), possesses an amorphous structure characterized by irregular atomic arrangements that make it hard, brittle, and a poor thermal conductor (**chemical aspect**) (Yulianeu et al., 2023). The amorphous structure of glass can be seen more clearly in the illustration in Figure 1.



(Source: e-education.psu.edu)

Figure 1. Amorphous Structure of Glass Illustration

Figure 1 shows that the glass structure is irregularly hexagonal in shape where one silicon atom is bonded to three oxygen atoms. Due to these properties, sudden temperature changes can produce uneven thermal expansion between the inner and outer surfaces of the bottle, generating stress that leads to cracking or breakage (**physics aspect**) (Wang et al., 2013).

The equipment sanitation process during the preparation stage of *jamu gendong* production is presented in Table 2.

Table 2. Description of the Processes in the Preparation Stage

Stage	Description	Documentation
Washing and Rinsing of Glass Bottles	This process is carried out to clean the glass bottles of *jamu* residue, making them appear cleaner and preventing any bad odor.	 (Source: Personal documentation)
Roasting of *Jamu Gendong* Raw Materials	The roasting process is carried out to ensure the *jamu* product is perfectly cooked, to reduce the bitter sensation, and to make the final product more durable.	 (Source: Personal documentation)

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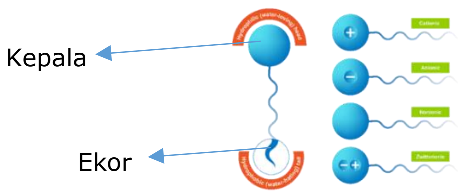
Based on Table 2, it shows that after an initial rinse, the bottles are filled with a mixture of clean pebbles and a soapy solution. Following this, the bottles are thoroughly rinsed with running water and rinsed again with hot water as a final sterilization step. Similarly, the rhizomes are soaked to facilitate the removal of attached soil before processing.

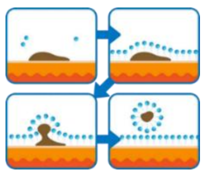
After an initial rinse, the bottles are filled with a mixture of pebbles and dish soap, then shaken vigorously to generate mechanical abrasion and turbulent flow that dislodges dirt from hard-to-reach areas (**physics aspect**). Dish soap contains surfactants such as sodium lauryl sulfate (SLS), which reduce surface tension and form micro-emulsions that dissolve oils and organic residues (Hartono et al., 2024). Surfactants possess hydrophilic heads and hydrophobic tails, enabling them to interact with both water-based and oil-based substances (Fiyani et al., 2021) (**chemistry aspect**). The surfactant agent's ilustration can be seen to get better understanding through Figure 2.



(Source: www.moleaer.com)

Figure 2. Surfactant Agent's Illustration

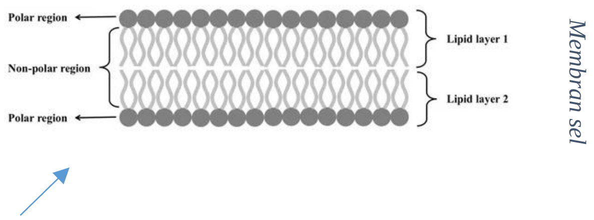
Figure 2 shows that the two different sides of a surfactant agent allow it to act like a molecular-level magnet, with the head attracting water molecules and the tail repelling them. This allows the surfactant to disrupt the cohession of fats and oils (Yuliatun dkk., 2024) (**chemistry aspect**). How surfactants work can be seen in Figure 3.

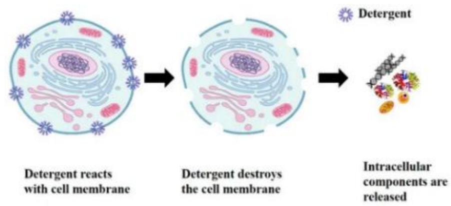


(Source: www.moleaer.com)

Figure 3. Illustration of How Surfactants Work

Figure 3 shows that an emulsification process occurs, causing the surfactant to form micelles that encapsulate lipid particles by breaking hydrogen bonds on the water surface. This process facilitates the removal of oils, kills bacteria, and dissolves organic debris (Emilia dkk., 2023; Sayed et al., 2023) (**chemistry aspect**). Surfactants also damage bacterial cell membranes, so that chemical lysis occurs as shown in Figure 4.





(Source: mdpi.com)

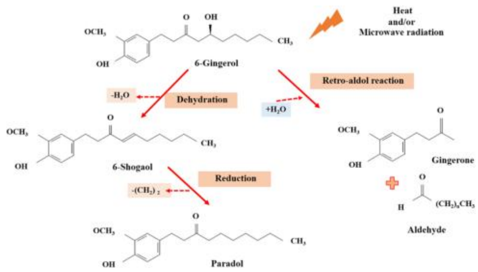
Figure 4. Illustration of Cell Membrane and Cell Membrane Lysis

Figure 4 shows that surfactants damaging bacterial cell membranes by solubilizing lipids, nucleic acids, and proteins, leading to membrane perforation and subsequent lysis (Nazzaro et al., 2013; Islam et al., 2017) (**biological aspect**). Following washing, bottles are rinsed thoroughly with running water and then rinsed again with hot water just before use. Hot water accelerates hydrolysis and removes soap residue more efficiently because higher temperatures increase molecular kinetic energy, thereby accelerating chemical reactions (Imman et al., 2018; Muchendu, 2024) (**chemistry aspect**). Heat also denatures membrane proteins and induces bacterial lysis, reinforcing its sterilizing effect (Islam et al., 2017). Producers perform this sanitation step twice daily because glass bottles used repeatedly in humid environments are highly susceptible to microbial contamination (Purnowo et al., 2024) (**biological aspect**).

In the preparation stage, there is a roasting process for the spices, rice, and ginger used in *jamu gendong* production. The roasting process uses an iron skillet because its conductiveness. Based on Table 2, it shows that there is a process for making the spices that are commonly added when making *jamu*. These spices are made from anise, cipir, and dawung, which are roasted and then ground. Afterward, the spices are put into a jar and are ready to be used at any time. There is also a process for making rice flour, which is one of the main ingredients in making *jamu* beras kencur. The process for making the rice flour is the same as for the spices, which is by roasting and grinding.

The roasting process involves both physical and chemical transformations, accompanied by heat transfer mechanisms. Heat from the stove is conducted to the pan, and during roasting, moisture within the ingredients evaporates, causing the materials to become drier, more brittle, and easier to crush (**physics aspect**) (Shakerardekani et al., 2011). These physical changes make the grinding process easier (Smrke et al., 2022).

Roasting also triggers several important chemical reactions. Heating activates the retro-aldol reaction, which converts the bioactive phenolic compound gingerol into zingerone in ginger (More et al., 2021). This transformation reduces the sharp pungency of fresh ginger and produces a warmer, sweet-spicy aroma (**chemistry aspect**) (Alharbi et al., 2022).



(source: researchgate.net)

Figure 5. Compound Changes in Ginger when Heated

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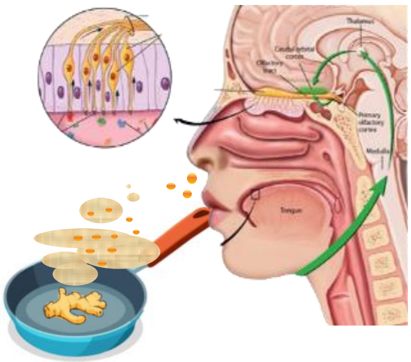
As shown in Figure 5, gingerol as the most abundant pungent component in fresh ginger, especially 6-gingerol which is thermally unstable. Upon heating or drying, gingerol undergoes dehydration to form shogaol, which is approximately twice as pungent. The dominant compound in dried ginger, 6-shogaol, is rarely found in fresh rhizomes. Under high temperatures or microbial metabolism, shogaol can further convert into paradol, a minor bioactive component. Heating also promotes the conversion of gingerol to zingerone through the retro-aldol pathway (Pázmándi et al., 2024). According to Supardan et al. (2012), gingerol decomposition into zingerone and shogaol occurs at temperatures above 45°C (**chemistry aspect**).

The aroma of *jamu* (herbal medicines) can be detected because humans have a sense of smell, the nose. An illustration of how the nose detects odors is shown in Figure 6.



(source: brainfacts.org)

Figure 6. The Illustration of Nose Detecting Odor

Figure 6 illustrates that smelling an odor involves the inhalation of small volatile molecules known as odorants or aroma compounds. These molecules stimulate the sensory olfactory neurons in the nasal olfactory epithelium through cilia equipped with approximately 400 distinct odorant receptors, with each olfactory sensory neuron (OSN) expressing only one receptor type, analogous to hundreds of lock-and-key pairs (Gonzalez-Kristeller et al., 2015). When an odorant binds to its matching receptor, an electrical signal is transmitted to the brain. Humans are estimated to distinguish up to 1.72 trillion different smells, as each OSN selectively responds to multiple odorants, and each odor activates a unique combinatorial pattern of OSNs. Differences in odor type or concentration are therefore encoded through specific "combinatorial receptor codes" within the olfactory epithelium (Kurian et al., 2021). This mechanism explains why changes in aroma during *jamu* production can be readily perceived (**biological aspect**).

The making/manufacturing stage involves a sequence of six key processes: cutting, washing, grinding, formulating, boiling, and filtering. The detailed identification of scientific knowledge in the making stage is presented in Table 3.

Table 3. Identification of Scientific Knowledge in The Making Stage

Process	Local Knowledge	Scientific Knowledge
Cutting of Herbs	Before grinding the ingredients, herbs are first chopped to facilitates the grinding process, whether using a pestle or blender.	Knife to chop is an application of the principles of inclined planes, force, and pressure (**physics aspect**). The knife moves due to biomechanism (**biology aspect**). Cutting herbs into smaller pieces increases their surface area (**physics aspect**).

Jamu Refinement	The chopped and washed herbs must first be ground using a blender or mortar and pestle. The grinding process aims to maximize the release of the nutrients trapped within the herbs.	This process helps to release of bioactive substances because their cell walls rupture (**biological aspect**). Plant cells exert turgor pressure to maintain their shape (**biological aspect**). Vortex formation occurs during the grinding process using a blender, which is an application of Bernoulli's principle (**physical aspect**). Energy and power are required for the grinding process using a blender (**physical aspect**).
Jamu Measuring	*Jamu gendong* producers weigh and measure ingredients during the preparation process to maintain consistent flavor. Sugar, salt, and lime are added to balance the flavors. Before and after the boiling process, producers periodically check the taste and add sugar or salt to achieve the desired flavor.	The use of scales and spoons is an application of science material on measurement (**physical aspect**). The addition of sugar and salt is an example of adding additives to food or drinks (**chemical aspect**). The process of tasting relies on the sense of taste, the tongue (**biological aspect**).
Jamu Boiling	The ground and blended spices are mixed in individual pans; water is added; heated to a boil to maximizes shelf life and reduces the bitter and spicy flavors.	This process is a traditional method for extracting active ingredients (**biological and chemical aspects**). Heat and energy transfer occurs (**physical aspects**). Physical and chemical changes occur during boiling, such as melting sugar, diffusion, and chemical reactions (**physical and chemical aspects**).
Filtering *Jamu*	The *jamu* that has been boiled until cooked is then aired briefly and then filtered using a flour sieve and a thin, porous cloth to separate the dregs from the herbal juice.	The filtration process involves a jerking motion, which is an application of Newton's Second Law (**physical aspect**).

The processes of cutting the herbs, refinement, measuring and formulating, boiling, also filtering in the *jamu gendong* production process in the making stage is presented in Table 4.

Table 4. Description of the Processes in the Making Stage

Stage	Description	Documentation
Cutting of Empon-empon	This process is done to remove unnecessary parts of the empon-empon and to facilitate the grinding process. The tool used for cutting is a kitchen knife.	 (Source: Personal documentation)
Grinding of *Jamu Gendong* Raw Materials	The empon-empon that has been cut and washed is ground with the help of a blender.	 (Source: Personal documentation)
Formulating *Jamu Gendong*	Measuring palm sugar, adding granulated sugar, salt, and lemongrass into each pot.	

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		(Source: Personal documentation)
Boiling of *Jamu Gendong*	The formulated *jamu* is boiled until it bubbles and is fully cooked.	 (Source: Personal documentation)
Filtering of *Jamu Gendong*	The cooked *jamu* is filtered several times using a fine sieve and a cloth until the *jamu* has as little sediment or fine pulp as possible.	 (Source: Personal documentation)

Based on Table 4, it shows that the cutting process for the empon-empon is done simply using a kitchen knife and a wooden cutting board. Ginger, in particular, is divided into two parts: one half is chopped to be ground together with galangal, and the other half is coarsely crushed for a sweet ginger infusion. The next step is the washing of the chopped empon-empon before the grinding process. This washing is done again to avoid contamination from dirt or germs, thus ensuring it is cleaner.

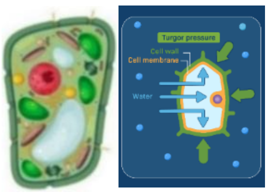
Scientific knowledge shown on the cutting process such as, the use of a kitchen knife represents an application of the inclined plane mechanism in simple machines, where the curved blade design allows for an efficient rocking motion that reduces wrist strain during daily use (**physics and biology aspects**) (Marsot et al., 2021). A sharp knife requires less effort because its narrow cutting edge concentrates force over a smaller area, thereby increasing pressure and reducing friction, in accordance with the equation (**physics aspect**) (Kumar et al., 2023). This is in accordance with the equation in the pressure principle as follows:

$$P = \frac{F}{A}$$

With equal applied force, a sharper blade produces greater pressure than a dull one, making cutting easier. Chopping herbs into smaller pieces also increases their surface area, enhancing contact with blender blades or a pestle and thus reducing mechanical workload, as larger pieces require greater force to process (**physics aspect**) (Demir et al., 2010).

Grinding Process of *Jamu Gendong* Raw Materials that presented in Table 4 shows that for the grinding process, a blender is typically used to pulverize the raw materials into a fine paste. The grinding is done in stages and separately for each type of *jamu*. The process of blending or pounding makes the *jamu* thicker and extracts more essence compared to *jamu* that is not ground.

Iin the *jamu* refining process, indicates that physical force such as pounding or grinding disrupts plant cell walls and membranes, causing cytoplasmic leakage that facilitates the release of pigments and bioactive compounds and increases their solubility in water (**biological aspect**) (Zhang et al., 2023; Wang et al., 2023). Plant cells are characterized by a rigid cell wall that protects and maintains cell shape, supported by turgor pressure as illustrated in Figure 7 (Kheyrodin et al., 2022; Beauzamy et al., 2015).



(source: tirto.id; labxchange.org)

Figure 7. Illustration of Plant Cells and Turgor Pressure

Figure 7 shows that turgor pressure, regulated through osmosis, plays roles in growth, transport, stomatal movement, and tissue rigidity (Yi et al., 2022). The vacuole also contributes as an osmoregulator, storing concentrated cell sap composed of water, minerals, enzymes, alkaloids, sugars, and metabolic residues (**biological aspect**) (Khan & Farhana, 2022; Andreev, 2001).

Grinding represents a physical change in which particle size is reduced without altering chemical composition to produce a thicker extract. Destroying the cell wall and vacuole is necessary for releasing encapsulated bioactive compounds. Grinding with a blender relies on the rapid rotational motion of blades, generated when electric current induces a magnetic field in the stator that drives the rotor, producing torque that rotates the blades (**physics aspect**) (Gerlando et al., 2024).

At the same time while grinding the formulas, the *jamu* producers are preparing additional ingredients in each pot, which will be filled with the ground results, as presented in Table 4. It shows that the *jamu* formulating process, which is done before boiling and at the same time as the grinding process. The *jamu* producers use a scale to weigh the palm sugar used for each *jamu*, adding coarsely crushed lemongrass, granulated sugar, a sufficient amount of salt, and the raw *jamu* materials that have been ground with a blender.

The process of formulating and measuring *jamu* shows that the measuring process involves scientific knowledge related to measurement and units. Scales or balances function as standard measuring instruments that produce more consistent results than spoons, which are considered non-standard tools (Salwa et al., 2023). *Jamu* producers use a sitting scale to measure the mass of sugar needed for each mixture, relying on fixed comparison weights ranging from 50 g, 100 g, 200 g, 500 g, to 1,000 g. Therefore, mass measurement with a scale is categorized as a standard unit. In contrast, using a spoon is considered non-standard because the amount measured can differ between individuals even when using the same spoon. Standard units have fixed values, yield consistent results, and are universally applicable, whereas non-standard units lack fixed values, cannot be systematically converted, and produce less accurate measurements (Mufidha et al., 2024) (**physics aspect**).

During the formulating process, producers combine palm sugar, granulated sugar, salt, and lemongrass before boiling them together with the ground herbs. These ingredients function as additives that enhance the quality of the *jamu*. Sugar helps balance the taste of bitter or strong flavors (Deoranto et al., 2021). Salt can enhances flavor, maintains electrolyte balance, and acts as an emulsifier that stabilizes color and viscosity (Rosa et al., 2022; Ngoualem et al., 2020). Lemongrass is added due to its bioactive compounds, such as phenolics, flavonoids, and essential oils, which contribute antioxidant and antimicrobial properties as well as a fresh aroma (Khasanah et al., 2024). It also has several health benefits, including anti-inflammatory, anti-obesity, antihypertensive, and antidiabetic effects (Puteri et al., 2020) (**chemistry aspect**).

Throughout and after boiling, producers evaluate taste through periodic tasting. The human tongue detects sweet, sour, bitter, salty, and umami tastes through papillae covered with pores containing taste buds (Spence, 2022). Each taste bud consists of 50–100 receptor cells that regenerate weekly, including gustatory cells responsible for sensing taste and basal cells that develop into new gustatory cells. Tastants must dissolve in saliva to diffuse into the taste pores and bind to gustatory hair proteins, triggering signals transmitted by neurons to the gustatory cortex. When the brain receives these signals, it prepares the digestive process by increasing

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saliva enzymes and gastric secretions (Mouritsen, 2015). Tasting is crucial in food production as part of organoleptic testing to ensure product quality (Ismanto, 2023) (**biology aspect**).

The boiling process in the production of *jamu gendong* as presented in Table 4 shows that this process uses an aluminum pot and heat from a stove. During boiling, it is stirred periodically. When it boils, foam that floats on the surface of the *jamu* must be removed to produce a clear *jamu gendong* product.

The *jamu* boiling process shows that the process contains scientific principles related to mass transfer and heat transfer. Boiling is a common method to extract bioactive compounds from empon-empon (Li et al., 2024). During boiling, water and solutes move through osmosis and diffusion, driven by concentration gradients that generate molecular kinetic energy (Manning & Kay, 2023; Jaeger et al., 1999). Elevated temperatures further increase molecular motion, accelerating diffusion and enhancing the release of bioactive compounds into the boiling water (Janek et al., 2012) (**biology and chemistry aspect**).

Heat transfer also plays a key role, boiling involves heat absorption as an endothermic reaction that requires thermal energy to overcome latent heat of vaporization (Jamilah et al., 2021; Rashidi et al., 2021). The amount of heat absorbed can be calculated using $Q = m.c.\Delta T$ or $Q = m.L$ (Muhsin, 2019) (**physics aspect**). Heat is transferred through conduction, convection, and radiation. Conduction occurs when the aluminum pot transfers heat from the stove flame to the *jamu* mixture (Rifky & Muharom, 2022), while convection currents form as hot water with lower density ($\rho = m/V$) rises and cooler water descends, distributing heat evenly (Baride & Maturbongs, 2018) (**physics aspect**).

The boiling of *jamu* also involves both physical and chemical changes. Physical changes result from variations in temperature or force and involve alterations in state, form, or size without producing new substances; these changes are often reversible (Dengen et al., 2019; Demircioğlu et al., 2013). Chemical changes occur when reactions form new substances with different chemical properties and are typically irreversible (Widyanto, 2020). In *jamu* boiling, physical changes include sugar melting, diffusion of compounds, and water boiling, while chemical changes include aldol degradation of bioactive compounds, Maillard reactions or caramelization, oxidation, and the breakdown of volatile components that release aromatic compounds such as eugenol (Milinda et al., 2021) (**physics and chemistry aspect**).

After it is cooked, the boiled *jamu* is removed from the stove, and the filtering process is carried out next, as presented in Table 4 shows that the *jamu* filtering process, which aims to separate the liquid from the solid residue (*ampas*). The filtering is done with the help of a flour sieve and a clean cloth. The filtering is performed 2-4 times until the filtered result has as little sediment as possible.

The squeezing and filtering process show that the processes involve key scientific principles. The shaking motion applied during filtering increases the acceleration of the liquid, thereby increasing the force that pushes the liquid through the filter pores, resulting in a greater volume of filtrate per unit time. This reflects Newton's Second Law, where acceleration (a) is directly proportional to the total force ($\sum F$) and inversely proportional to mass (m), expressed as $a = \sum F/m$ (Silaban et al., 2024) (**physics aspect**). Filtration itself is a separation method based on particle size differences between suspended solids and dissolved substances (Aprilianto & Oktaviananda, 2024) (**chemistry aspect**). Because flour sieves have pores that are not fine enough to separate small herbal residues, repeated filtering is performed and followed by finer cotton cloth filtration to produce a concentrated yet clear *jamu* product. This multistage filtration improves beverage quality and enhances consumer comfort.

After filtering is complete, the *jamu* is packaged into glass bottles that have been sterilized with hot water, as presented in Table 5.

Table 5. Description of the *Jamu Gendong* Packaging Stage

Stage	Description	Documentation
Packaging of *Jamu Gendong*	The filtered *jamu* is poured into bottles and then hot water is poured in	 (Source: Personal documentation)

Based on Table 5, it shows that shows the final stage, which is the packaging of *jamu gendong* into glass bottles. Each type of *jamu* is poured into the glass bottles using a funnel and a small sieve as a precaution in case any impurities remain. After that, boiling water is poured into each bottle of *jamu* with the aim of ensuring it is more thoroughly cooked and to improve its shelf life, especially for *jamu* beras kencur, whose process is different from other types of *jamu*. Beras kencur is made by cooking the ingredients separately and then mixing them at the end without further boiling, making it less durable than other types of *jamu* that are boiled until fully cooked. The packaging stage is divided into the process of pouring the *jamu* into glass bottles and then pouring hot water. A detailed identification of the scientific knowledge of the packaging process is presented in Table 6.

Tabel 6. Identifikasi Pengetahuan Ilmiah pada Tahap Pengemasan

Process	Local Knowledge	Science Knowledge
Product Packag-ing	Product packaging can reduce exposure to dust and dirt. *jamu* in plastic bottles should be stored in a dark place, as the plastic taste can develop in hot environments. Glass bottles should be placed on top to prevent breakage.	Proper product packaging and storage can maintain product quality by reducing oxidation reactions and exposure to microorganisms from the external environment (**biological and chemical aspects**). Plastic and glass bottles have different material characteristics; both have their own advantages and disadvantages (**chemical aspects**).

Based on the table 6, the packaging stage plays a crucial role in maintaining the quality and extending the shelf life of traditional herbal drinks. Proper packaging minimizes exposure to microorganisms such as *S. aureus, P. aeruginosa, Shigella spp., Salmonella spp., E. coli, A. parasiticus, A. flavus, A. niger*, and *A. ochraceus* (Ansari et al., 2024) and reduces contact with oxygen which is an essential factor in oxidation, ROS formation, and degradation of organic compounds (Kaneto & Uto, 2024; Juan et al., 2021), as well as the growth of aerobic microbes (Mafe et al., 2024) (**biological and chemical aspects**).

Differences in packaging materials further influence storage practices. Glass bottles are inert, thermally stable, and better at preserving antioxidant properties (Kim et al., 2011; Nielsen & Pedersen, 2022; Zhang et al., 2025), supported by their amorphous SiO_2-based structure (Gerhard & Köhler, 2024). In contrast, plastic bottles are lightweight and durable but may release BPA or VOCs when exposed to heat or sunlight (Soong et al., 2022; Liu et al., 2024) (**chemical aspect**). During the pouring stage, boiling water is used for sterilization and acts as an alternative to direct boiling, especially for *jamu beras kencur*, which are not boiled to avoid gelatinization, a process in which starch (amylose and amylopectin) absorbs water, swells, and thickens (Chen et al., 2021; Fu et al., 2025; Wang et al., 2019) (**chemical aspect**). This hot-pouring step effectively reduces spoilage-causing bacteria (**biological aspect**). An alternative preparation method involves separately boiling sugar, lemongrass, and cinnamon to maximize

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extraction of bioactive compounds such as cinnamaldehyde (Abeysekera et al., 2019) and essential oils and flavonoids in lemongrass (Hashim et al., 2019; Guleria & Sehgal, 2020). Boiling water further sterilizes the final mixture without excessive gelatinization (Zhang et al., 2014), whereas raw water may contain pathogenic microorganisms that cause gastrointestinal disturbances (Babič et al., 2017) (**biological aspect**).

The Potential of Scientific Knowledge

The scientific knowledge embedded within the traditional *jamu gendong* production process demonstrates strong potential to foster middle school students' basic thinking skills, encompassing cause and effect, transformation, relationship/correlation, classification, and qualification (Presseisen & Barbara, 1984). The scientific knowledge contained in the production process of *jamu gendong* has the potential to empower basic thinking skills as presented in Figure 8.

Based on Figure 8, it shows that the stages of the production process of *jamu gendong* have the potential to empower basic thinking skills. The explanation of the potential of the *jamu gendong* production process for empowering basic thinking skills is as follows.

1. Process of tools and materials preparation

This process has the potential to empower basic thinking skills, particularly the indicator **classification**. Students observe, identify, and categorize tools and materials based on characteristics such as type, function, and physical form.

2. Process of tools and materials sanitation

The sanitation step supports the **cause and effect** indicator because students learn how unclean equipment can cause microbial contamination. Dishwashing soap contains surfactants such as SLS that can disrupt bacterial membranes (Islam et al., 2017). This process also involves scientific aspects where water temperature, friction, microbes, and surfactants, allowing students to identify **relationships/correlations** among concepts.

3. Process of roasting

Roasting supports **cause and effect** as students observe physical and chemical changes caused by heat transfer, such as reduced moisture, intensified aroma, and texture modification (Shakerardekani et al., 2011; Alharbi et al., 2022). This stage also empowers **transformation**, as students connect prior knowledge with new scientific understanding, including Maillard reactions and the release of volatile compounds responsible for aroma (Bai et al., 2022; Wang et al., 2021;Vedashree et al., 2020; Shelake & Dabhi, 2019). Students may also practice **classification** by comparing ingredients before and after roasting.

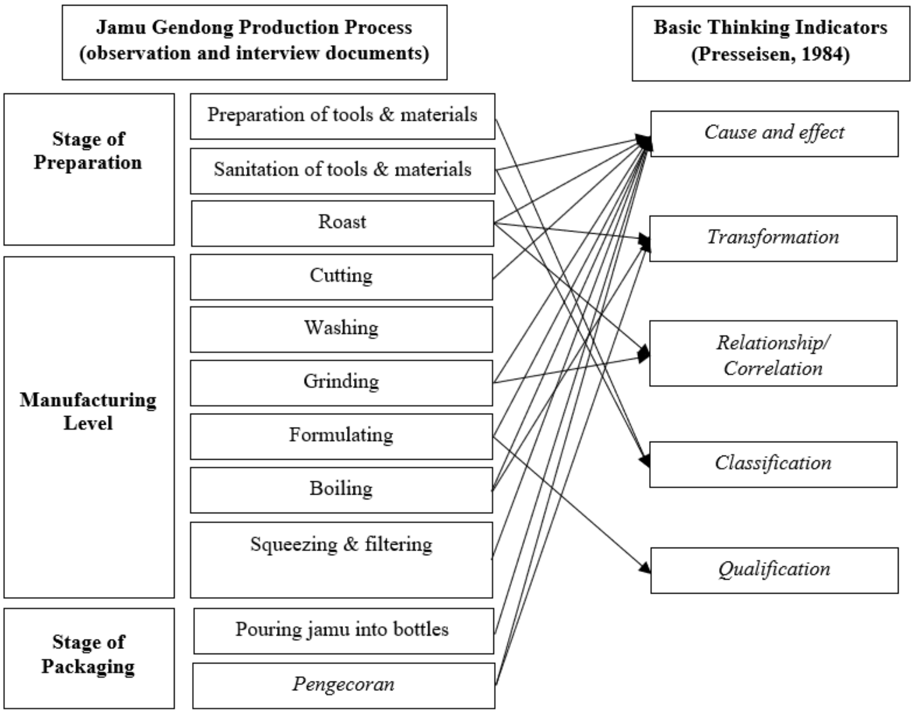

Figure 8. Potential of the Production Process of *Jamu Gendong* on Basic Thinking Skills

4. Process of cutting

Cutting empon-empon supports **cause and effect** because reducing particle size increases surface area, decreasing the force required for grinding (Demir et al., 2010). The concept can be connected to students' daily experience such as the use of powdered sugar to speed up mixing. This analogy strengthens the **transformation** indicator by linking prior experiences with new scientific reasoning.

5. Process of grinding

Grinding supports **cause and effect**, as smaller particle size reduces resistance on blender blades or pestles (Demir et al., 2010). As with cutting, students may connect this concept to their experience using powdered sugar in baking, supporting **transformation** by linking familiar activities to new scientific concepts.

6. Process of formulating

Formulation involves adding sugar and salt to balance taste, regulate viscosity, and influence color (Deoranto et al., 2021; Rosa et al., 2022; Ngoualem et al., 2020). Students practice **cause and effect** by predicting how additives affect the sensory quality of *jamu*. Sensory evaluation (organoleptic testing) trains students in **qualification**, as they observe, record, and compare visual, aromatic, and taste attributes (Wahyuningtias, 2010).

7. Process of boiling

Boiling empowers **cause and effect** since heat increases molecular kinetic energy, accelerating diffusion of bioactive compounds. Students may form hypotheses such as comparing *jamu* produced by boiling versus steeping. Boiling also develops **transformation**, as students connect everyday observations (e.g., boiled drinks are safer to drink) with the scientific principle that heating destroys microbes.

8. Process filtering

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Filtering with repeated shaking increases fluid acceleration, thus increasing the force pushing the liquid through the pores. This aligns with Newton's Second Law, $a = \Sigma F/m$ (Silaban et al., 2024). Students identify causal relationships, supporting **cause and effect**. They also observe that different filter pore sizes influence clarity, reinforcing scientific reasoning.

9. Pouring *jamu* into bottles

Proper packaging is essential because exposure to oxygen, sunlight, or microbial contaminants (e.g., *E. coli*, *S. aureus*, *Aspergillus* spp.) accelerates spoilage. Packaging acts as a barrier against oxidation, microbial growth, and chemical degradation (Liu et al., 2024; Juan et al., 2021). This supports **cause and effect**, as students link packaging quality with product safety and shelf-life.

Table 7. The Relationship of Science Material and Scientific Knowledge in the Production Process of *Jamu Gendong*

Class	Scope of Material	Scientific Knowledge in the Production of *Jamu Gendong*
VII	The Nature of Science and the Scientific Method	Designing experiments using the scientific method
		Measuring the composition of *jamu* with a scale and spoon
	Substances and Their Changes	Changes in glass structure when heated
		Physical and chemical changes when cooking *jamu*
		Diffusion and evaporation events when boiling *jamu*
		Separation of suspension during *jamu* filtration
		Amorphous structure and inert properties of glass bottles
	Temperature, Heat and Expansion	Expansion of substances due to changes in temperature
		Changes and heat transfer and expansion of water when cooking *jamu*
	Movement and Style	The jerking motion when filtering the *jamu*
VIII	Cell Introduction	Destruction of cell membranes when reacting with surfactants
		Plant cell structure, turgor pressure, release of bioactive compounds when *jamu* is ground
		Metabolism of bacterial cells that cause decay
	Structure and Function of the Bodies of Living Creatures	Additives in *jamu* preparations
		Digestive disorders due to consuming undercooked water
	Work, Energy and Simple Machines	The use of a knife as an application of the inclined plane principle
		The kinetic energy in the rotating movement of the blender blades is able to destroy cell walls
	Elements, Compounds and Mixtures	SLS as a surfactant in dishwashing soap
		Process of filtering *jamu*
IX	Human Coordination, Reproduction and Homeostasis System	The nose's ability to detect changes in aroma during roasting
		Organoleptic testing of *jamu* using the sense of taste
		The brain's response to receiving stimuli from the five senses
	Pressure	The area of contact of the blade affects the pressure
	Electricity, Magnetism, and Alternative Energy Sources	There is an energy transformation when blending *jamu*
	Reaksi-Reaksi Kimia dan Dinamikanya	Washing glass bottles with hot water can speed up the hydrolysis reaction
		The boiling process increases the rate of reaction and diffusion
		Jamu is susceptible to oxidation if not packaged properly
		Exposure to oxygen and the environment supports microbial metabolism
		Galangal rice is processed separately to avoid gelatinization reactions
		Photo-hydrolysis of glass bottles

10. Process of *pengecoran*

In *jamu beras kencur*, heating rice directly would trigger starch gelatinization, producing porridge-like texture (Wang et al., 2019; Chen et al., 2021). Students explore **cause and effect** by understanding how different heat treatments produce different outcomes. Analogies to everyday experiences (e.g., rice turning mushy when overcooked) support **transformation**, allowing students to generalize scientific principles to multiple contexts.

The Relationship of Science Material and Scientific Knowledge in the *Jamu Gendong* Production Processes

The scientific knowledge within the production process of *jamu gendong* can be used as a science learning resource. The mapping of it's scientific knowledge in junior high school science material is presented in Table 7.

CONCLUSION

Based on the results and discussion, it can be concluded that the formulation of the reasearch problem can be answered, namely: 1) the *jamu gendong* production process contains scientific knowledge that include several aspects such as biology, physics, and chemistry; 2) the *jamu gendong* production process that includes: (1) the process of tools and materials preparation; (2) the process of tools and materials sanitation; (3) the process of roasting; (4) the process of cutting; (5) the process of grinding; (6) the process of formulating; (7) the process of boiling; (8) the filtering process; (9) pouring jamu into bottles; and (10) process of *pengecoran* have the potential to empower junior high school students' basic thinking skills.

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