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Model of Educational Reconstruction in Integrating Ciayumajakuning Ethnoscience into Chemistry Learning

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ABSTRACT

This study aims to reconstruct the ethnoscientific contexts of the Ciayumajakuning region (Cirebon, Indramayu, Majalengka, and Kuningan) into chemistry learning materials using the Model of Educational Reconstruction (MER) framework. A descriptive qualitative design was employed, integrating field surveys, literature review, and expert validation. Data were obtained from 17 respondents and scientific literature related to selected local wisdom contexts. The analysis identified five contexts with strong chemical relevance: *batik Mega Mendung*, *wayang kulit*, *siraman panjang* (jamasan), *bata dan genteng Jatiwangi*, and *peuyeum ketan*. Each was analyzed for its scientific structure and mapped against the high school chemistry curriculum within the *Merdeka Curriculum* framework. Results indicate that these local wisdoms represent diverse chemistry concepts, including organic and inorganic reactions, material transformation, and biochemistry, though their distribution across topics remains uneven. The study demonstrates that MER provides a systematic approach to transforming cultural practices into pedagogically sound learning contexts. The reconstructed models are expected to support the development of contextual, culturally responsive chemistry learning materials that strengthen students' scientific literacy and appreciation of local culture.

INTRODUCTION

Chemistry learning in secondary schools is often perceived as abstract and lacking relevance to students' local experiences, which contributes to the declining interest and limited meaningful engagement in learning (Andriani et al., 2019; Sakmawati et al., 2023; Weni Mandasari et al., 2025). This condition is reflected in the consistently low performance of Indonesian students in international assessments. The science literacy scores of Indonesian students in PISA 2009, 2012, 2015, 2018 and 2022 were 383, 382, 403, 396, and 366 respectively—far below the OECD average range of 493–501. In addition to low scores, Indonesia ranked 57th out of 65 countries (2009), 64th out of 65 (2012), and 62nd out of 70 (2015), 70th out of 79 countries (2018), and 67th out of 81 countries (2022), indicating persistent weaknesses in students' ability to connect scientific knowledge with real-life contexts (Yanto et al., 2025; Yusmar & Fadilah, 2023). These findings reinforce that chemistry learning in Indonesia still requires approaches that enhance contextual relevance and bridge abstract concepts with students' lived experiences. One increasingly proposed strategy is utilizing local wisdom (ethnoscience) as a learning context to make chemistry concepts more relevant, meaningful, and oriented towards real community problems (Dewi et al., 2019; Sutrisno et al., 2020). In Indonesia, this idea is growing rapidly: studies on the development of ethnoscience-based learning tools, ethno-STEM learning models, and the application of ethnochemistry to improve chemical literacy have been consistently reported in the last decade (Aldiansyah et al., 2023; Dewi et al., 2019; Primadianningsih et al., 2023).

While national discourse on ethnoscience integration continues to expand (Fiqry & Agustinasari, 2025; Sari et al., 2023), a notable research gap persists: there has been no systematic educational reconstruction of local wisdom that explicitly aligns their scientific structures with the *Kurikulum Merdeka*. Most prior studies focus only on identifying or describing cultural phenomena without conducting didactic reduction, curriculum alignment, or mapping their conceptual relevance to chemistry learning outcomes. To transform cultural practices into accurate and teachable science materials, a framework capable of bridging scientific structures and pedagogical needs is needed (Fiqry & Agustinasari, 2025; Mustafa et al., 2024; Syazali & Umar, 2022). The Model of Educational Reconstruction (MER) offers such a framework with three core components: (1) clarification and analysis of scientific substance, (2) investigation of student and teacher perspectives/conceptions, and (3) design and evaluation of learning environments (Duit et al., 2012). MER has been widely used to reconstruct new scientific domains or specific contexts to make them suitable for teaching (including design studies in chemistry); its contemporary application is supported by the science education R&D literature (Petchey & Niebert, 2021). Within the *Kurikulum Merdeka*, deep learning is framed through three essential pillars—mindful, meaningful, and joyful learning—each of which aligns naturally with the principles of MER.

The MER framework promotes mindful-learning by encouraging learners to examine cultural practices through scientific reasoning, fostering awareness of how everyday phenomena are grounded in chemical principles. It supports meaningful learning by reconstructing scientific content from contexts that are culturally familiar to students, allowing abstract concepts to be understood through personally relevant experiences. At the same time, MER facilitates joyful learning by integrating authentic, locally embedded practices—such as batik-making, fermentation, or metal cleansing—into instructional activities that stimulate curiosity and engagement. Through this alignment, MER not only strengthens the conceptual foundation of chemistry learning but also resonates with the pedagogical vision of the *Kurikulum Merdeka*, which emphasizes contextual, holistic, and culturally responsive learning experiences.

Furthermore, the Ciayumajakuning region—which hosts a wide range of cultural practices that inherently involve chemical processes —remains largely underrepresented in ethnochemistry research. This situation underscores the necessity for a study that not only identifies local wisdom but reconstructs it into scientifically accurate and pedagogically meaningful learning content that can strengthen contextual and culturally responsive chemistry instruction. Based on the background and research gaps mentioned above, this study aims to map the local wisdom of the Ciayumajakuning region that has the potential to be developed in contextual chemistry learning. The results of this mapping are then reconstructed in a scientific structure using the MER framework, ready to be developed into a contextual learning tool aligned with the learning outcomes of high school chemistry. The results of this study can be further developed for the development of teaching materials and learning strategies in the classroom.

METHODS

Research Design

This study employed a descriptive qualitative design framed within the Model of Educational Reconstruction (MER), which is developed in the late 20th century, primarily in German and European science education research, to systematically reconstruct scientific topics for educational purposes (Silva et al., 2024). The MER framework serves as a bridge between scientific structures and cultural experience, enabling culturally embedded practices to be transformed into scientifically accurate and pedagogically accessible learning content. This makes MER particularly relevant for integrating ethnoscience into chemistry education, as it systematically guides the transformation of complex cultural practices into teachable concepts that align with curriculum objectives and learners' cognitive readiness.

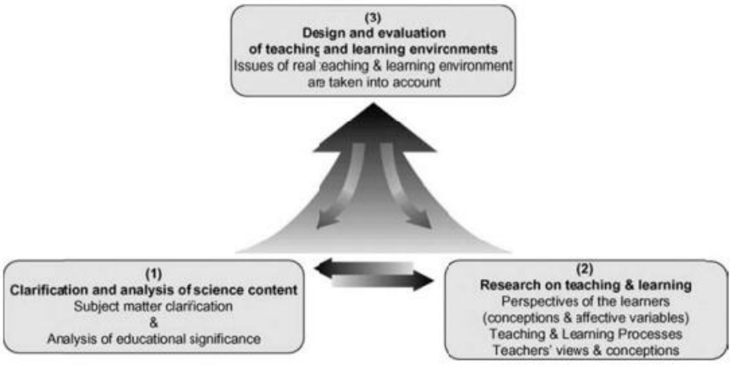

Figure 1. The three components of the Model of Educational Reconstruction ((Duit et al., 2012)

In this research, the MER was used as an analytical lens to systematically map and reconstruct local wisdom (ethnoscientific) contexts from the Ciayumajakuning region (Cirebon, Indramayu, Majalengka, and Kuningan) that are relevant for contextual chemistry learning at the secondary school level. The MER framework was operationalized primarily within the first two components—the reconstruction of scientific substance and the investigation of practitioners' and community perspectives—providing a conceptual and empirical foundation for understanding the cultural–scientific potential of Ciayumajakuning. The study did not extend to the third MER component, which concerns the design and empirical evaluation of learning environments, as its primary focus was to establish a validated scientific and contextual reconstruction that can inform subsequent development of instructional materials. The design integrates field survey, literature review, and expert validation as a triangulated qualitative process, ensuring the robustness and reliability of the reconstructed educational content.

Research Target

The research targeted three main entities:

- Human sources (informants) — 17 respondents consisting of chemistry education lecturers, science teachers, and local cultural practitioners were involved in the identification of ethnoscientific practices.
- Cultural artifacts and practices — local traditions, crafts, and products that represent scientifically interpretable processes such as *batik*-making, *keris* cleansing (*jamasan*), *peuyeum ketan* fermentation, ceramic tile (*genteng Jatiwangi*) production, and leather crafting for *wayang kulit*.
- Geographical scope — Ciayumajakuning was selected because it encompasses a wide range of cultural traditions that directly involve chemical processes, offering strong scientific potential for conceptual mapping and contextual learning development.

This multi-target design allowed the research to link empirical field data with cultural–scientific interpretation under the MER perspective.

Research Data

In this study, the collected data consisted of survey results identifying local wisdom in the Ciayumajakuning region and documents derived from a literature review on the predetermined content and context of local wisdom. The survey data were obtained from respondents residing in the Ciayumajakuning area, while the documentary data from the literature review were sourced from scholarly references, including journal articles and textbooks.

Research Instruments

Several instruments were developed to ensure systematic data collection and alignment with the MER analytical stages:

Table 1. Data Collection of the Study

No	Data	Technique	Instrument
1	List of local wisdom originating from the Ciayumajakuning region	Local wisdom identification survey in Ciayumajakuning; Field observation	Questionnaire sheet; Observation guideline
2	Scientific structure of local wisdom contexts	Literature study	Analysis sheet for the scientific structure of local wisdom contexts
3	High school chemistry concepts related to local wisdom contexts	Document analysis	Analysis sheet of the relationship between local wisdom scientific content and the high school chemistry curriculum

Each instrument was reviewed by two chemistry education lecturers to ensure content validity and alignment with MER dimensions. Reliability was enhanced through triangulation among field data, literature sources, and expert validation.

Data Analysis

Data analysis was carried out qualitatively following the logic of MER and supported by descriptive statistics for summarizing the frequency of identified contexts.

1. Survey Results on the Identification of Local Wisdom in the Ciayumajakuning Region
   Data obtained from respondents in this survey were compiled into an inventory consisting of a list of names, descriptions, and the contextual origins of the local wisdom. The data were then screened to determine which contexts had the potential to be developed into chemistry learning materials. The main criterion for this selection was the extent to which elements of local wisdom intersected with chemical concepts that could explain them.
2. Analysis of the Scientific Structure of Local Wisdom Contexts
   The scientific structure of the local wisdom contexts was derived through a literature review of journal articles and textbooks related to the analyzed contexts. The review focused on components of local wisdom that were rich in chemical concepts. Based on several references, a foundational text describing the scientific structure of the local wisdom contexts was developed. The validity of scientific content was ensured through expert review, in which two chemistry experts evaluated the accuracy of the scientific structures derived from each cultural context.
3. Analysis of High School Chemistry Concepts Related to Local Wisdom Contexts
   High school chemistry concepts related to local wisdom contexts were analyzed in accordance with the current high school chemistry curriculum structure. This was based on the assumption that not all scientific structures of local wisdom contexts align with the cognitive level of high school students. The validity was confirmed by matching the identified concepts with the high school chemistry learning outcomes. This validation procedure guarantees that the mapped cultural-scientific elements meet both disciplinary standards and curriculum requirements. The results of this analysis served as the foundation for developing a content–context mapping framework of local wisdom to be integrated into high school chemistry learning.

RESULTS AND DISCUSSION

Identification of Local Wisdom Contexts

The identification process of local wisdom contexts was carried out through survey distribution and exploration using the Google search engine. The survey was designed to solicit community-based perspectives on local wisdom in a general sense, without restricting responses to practices involving chemical processes. This was intended to allow respondents to freely express culturally significant traditions, thereby generating a rich and diverse dataset that reflects the cultural landscape of Ciayumajakuning. It consisted of four questions regarding the respondent's region of origin, the local wisdom from that region, and its description. The survey was distributed in the form of a Google Form to respondents residing in the Ciayumajakuning area. A total of 17 respondents participated in the survey, and the results are presented as follows:

The survey did not yield any local wisdom originating from Kuningan Regency. Therefore, additional data collection was conducted through Google searches. This process identified several distinctive forms of local wisdom from Kuningan, such as *saptonan*, *archery traditions*, *seren taun*, and *pesta dadung*, as well as several traditional foods, including *tahu susu*, *jeniper*, and *peuyeum ketan*.

Based on the survey results, an analysis was conducted to determine the potential of each local wisdom context for integration into chemistry learning. This process served as an initial screening prior to conducting an in-depth literature analysis of each context and its related chemistry concepts. The results of this analysis are presented in Table 2 below.

Tabel 2. Identification of Local Wisdom in the Ciayumajakuning Region and Its Description

No	Local Wisdom	Potential		Description
		Yes	No	
1	*Batik mega mendung*	✓		Related to the components and dyeing process
2	*Wayang kulit*	✓		Related to materials (buffalo hide and pigments)
3	*Bubur suro*		✓	-
4	*Mudun lemah*		✓	-
5	*Obrog*		✓	-
6	*Ngunjung buyut*		✓	-
7	*Tawurji*		✓	-
8	*Ngapem*		✓	-
9	*Kesenian burok*		✓	-
10	*Tari topeng*		✓	-
11	*Cuci keris/siraman panjang*	✓		Related to the physical and chemical properties of iron
12	*Nadran*		✓	-
13	*Grebeg mulud*		✓	-
14	*Mapag tamba*		✓	-
15	*Mapag sri*		✓	-
16	*Guar bumi*		✓	-
17	*Mandi di sumur saat bulan Mulud*		✓	-
18	*Opak*		✓	-
19	*Munjung*		✓	-
20	*Bata dan genteng Jatiwangi*	✓		Related to the process and constituent materials
21	*Saptonan*		✓	-
22	*Seren taun*		✓	-
23	*Kawin cai*		✓	-
24	*Pesta dadung*		✓	-
25	*Sintren*		✓	-
26	*Peuyeum ketan*	✓		Related to the process and additional materials (including the type of wrapping)

Although the survey yielded 26 forms of local wisdom across Ciayumajakuning, only certain practices demonstrated strong chemical relevance, such as processes of fermentation, metal oxidation and preservation, clay transformation, and organic dye reactions. These chemistry-rich contexts were subsequently selected for reconstruction, as they offer the most substantial potential for contextual chemistry learning. The five selected local wisdom contexts are: *wayang kulit* (shadow puppetry), *siraman panjang* (traditional purification ritual), *bata dan genteng Jatiwangi* (Jatiwangi bricks and roof tiles), and *peuyeum ketan* (fermented sticky rice).

Analysis of the Scientific Structure of Local Wisdom Contexts

1. ***Peuyeum Ketan* (Fermented Glutinous Rice)**

Peuyeum ketan (fermented glutinous rice) is a traditional Indonesian food product produced through a natural fermentation process. It is made by steaming glutinous rice (*Oryza sativa* var. *glutinosa*) and adding fermentation starters containing yeast cultures. During fermentation, the rice grains partially liquefy, producing a sweet, slightly sour, and mildly alcoholic taste. Traditionally, *peuyeum ketan* is consumed as a snack or dessert during cultural festivals such as Ramadan celebrations, but it is now also produced commercially as a regional specialty souvenir (Nuraida, 2015).

In the Kuningan region, two major variants exist—white and black *peuyeum ketan*. The white type often exhibits a greenish hue derived from the addition of natural plant extracts such as *katuk* leaves (*Sauropus androgynus* L. Merr), *suji* leaves (*Dracaena angustifolia*), or *pandan* (*Pandanus amaryllifolius*). The product is typically wrapped in *Syzygium aqueum* (rose apple) leaves or banana leaves, a traditional practice that contributes to both flavor and preservation.

From a biochemical standpoint, *peuyeum* fermentation exemplifies a complex series of enzymatic reactions involving yeast microorganisms, particularly *Saccharomyces cerevisiae*. The process yields probiotic-rich foods with recognized benefits for gastrointestinal health (Gobbetti et al., 2010; Selhub et al., 2014). The yeast's enzymes act as biocatalysts, hydrolysing the starch in glutinous rice into simpler sugars. Initially, amylase converts starch into maltose, which is subsequently broken down by maltase into glucose (Harmayani et al., 2017; Wahyuningsih et al., 2023). The generated glucose accounts for *peuyeum*'s characteristic sweetness.

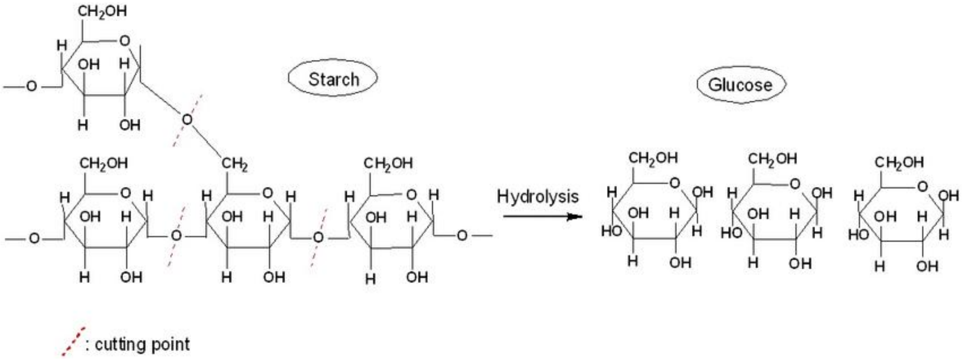

Figure 2. Hydrolysis of starch by amylase enzyme (Cahyana & Adiyanti, 2021)

As fermentation time increases, the glucose concentration rises proportionally (Wardani et al., 2022; Xie et al., 2022), and further enzymatic activity leads to the conversion of glucose into ethanol via the *zymase*-catalysed reaction:

$$C_6H_{12}O_6 + \text{zymase} \rightarrow 2\ C_2H_5OH + 2CO_2$$

The ethanol content of *peuyeum* is influenced by multiple factors, including wrapping material, soaking duration, and additive use. Rofiqoh et al. (2022) found that rose apple leaves produced the best fermentation outcomes compared to banana, mango, or *Morinda citrifolia* (noni) leaves. The *peuyeum* wrapped in rose apple leaves exhibited higher sweetness and acidity levels, with a relatively low ethanol content (0.50%). Similarly, Wardani *et al.*, (2022) reported that pre-soaking the glutinous rice without adding fruit extracts yielded the highest product quality—characterized by soft texture, bright white color, fresh aroma, and moderate sweetness—with an ethanol concentration of 2.936%. These findings confirm that the local wisdom of using rose apple leaves as wrapping material aligns with optimal biochemical fermentation outcomes.

The distinct aroma of *peuyeum* arises from ester compounds formed during fermentation. Ethanol reacts with organic acids in an esterification reaction, producing ethyl acetate—the main volatile responsible for the characteristic aroma. This reaction can be represented as:

$$CH_3COOH + C_2H_5OH \rightarrow CH_3COOC_2H_5 + H_2O$$

Higher ethanol concentrations correlate with stronger aromatic intensity (Lu et al., 2025), while additional aromatic profiles may derive from phenolic and polyphenolic compounds present in natural leaf wrappings. This interaction between fermentation chemistry and indigenous processing techniques reflects the integration of empirical scientific principles—such as hydrolysis, oxidation–reduction, and esterification—within local cultural practices. Hence, the *peuyeum* production process represents a contextualized illustration of chemical transformations in everyday life, providing a scientifically valid yet culturally resonant context for chemistry learning.

2. *Jamasan* (Metal Cleansing Tradition)

The *jamasan* is a traditional cleansing ritual practiced in Cirebon, particularly within the palaces of Kasepuhan and Kacirebonan, as well as in several *buyut* (ancestral mosques) across the region. The ceremony involves the ritual purification of heirlooms—such as krises, spears, staffs, and other metallic artefacts—and is typically performed annually during the Islamic month of *Muharram*, particularly between the 1st and 10th days, in conjunction with sacred observances such as *Lailatul Qadar* (the Night of Power) or the commemoration of the Prophet Muhammad's birthday. Symbolically, the ritual reflects the purification of the human self, both physically and spiritually, emphasizing moral introspection and renewal.

Scientifically, the ritual represents an indigenous application of chemical principles, particularly oxidation–reduction reactions and corrosion inhibition. The cleansing sequence consists of several stages: initial washing with coconut water and citrus juice, gentle scrubbing with lime, rinsing with floral water, drying, and final fumigation with aromatic oils such as musk, jasmine, or anti-rust herbal oils. The traditional use of acidic natural substances like coconut water and lime serves a functional purpose—to remove rust and inhibit the formation of iron oxides on metallic artefacts.

Corrosion occurs when metals undergo electrochemical oxidation upon contact with moisture or oxygen in the surrounding environment. Oxygen and hydrogen in air or water are reduced, while the metal itself is oxidized to form hydrated iron(III) oxide $Fe_2O_3.nH_2O$, commonly known as rust. The anodic oxidation of iron metal produces ferrous ions and electrons, which are subsequently consumed by the cathodic reduction of oxygen.

$$2Fe\ (s) \rightarrow 2Fe^{2+}\ (aq) + 4e^-$$
$$O_2\ (g) + 4H^+\ (aq) + 4e^- \rightarrow 2H_2O\ (l)$$
$$4Fe^{2+}\ (aq) + O_2\ (g) + (4{+}2n)H_2O\ (l) \rightarrow 2Fe_2O_3.nH_2O\ (s) + 8H^+\ (aq)$$

Within the *jamasan* ritual, coconut water and citrus extracts act as natural corrosion inhibitors, preventing or slowing down the redox processes responsible for metal deterioration. Corrosion inhibitors are compounds that, even in small quantities, can significantly reduce the corrosion rate by forming a protective layer on the metal surface (Chauhan et al., 2022). The organic acids and polyphenolic compounds—especially tannins—present in coconut water contribute to this protective mechanism. Tannins are weakly acidic polyphenols capable of forming stable coordination complexes with metal ions, resulting in the formation of iron–tannate complexes, as represented below (Qian et al., 2013):

$$Fe^{3+} + \text{Tannin} \rightarrow \text{Fe–Tannate Complex}$$

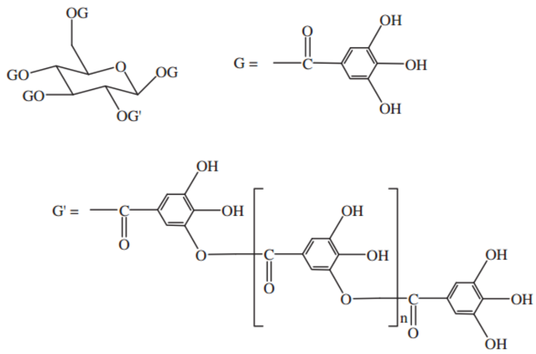

Figure 3. Molecular structure of tannins

This complex acts as a surface film that limits further oxidation of the metal by blocking active corrosion sites. Such indigenous practices illustrate a sophisticated empirical understanding of electrochemical reactions, demonstrating how traditional cultural knowledge can be scientifically interpreted within the framework of corrosion chemistry. The *jamasan* ritual therefore embodies an implicit model of material preservation rooted in local wisdom, integrating moral, cultural, and chemical dimensions into a unified scientific narrative.

3. Clay Roof Tile

The production of clay roof tiles (*genteng tanah liat*) in Majalengka has long been a distinctive local industry, dating back to the Dutch colonial period. Its origin was linked to the establishment of sugar factories in the region, which encouraged local communities to utilize nearby clay deposits for brick and tile manufacturing as a cost-efficient building material. Since then, clay roof tile production has become a key source of livelihood for local artisans.

The main raw material for tile production is clay (hydrated aluminum phyllosilicate), commonly mixed with rice husks to improve texture and porosity before being pressed and fired. The quality of the final product is largely determined by the type of clay and firing temperature, which influence the water absorption capacity and compressive strength of the tiles (Das et al., 1998).

Clay minerals typically consist of fine particles (< 2 µm) with layered crystalline structures composed of silica tetrahedral and alumina octahedral sheets. The tetrahedral units consist of one silicon atom surrounded by four oxygen atoms, forming a silica sheet, whereas the octahedral units are formed by six hydroxyl groups surrounding an aluminum atom, creating a gibbsite or brucite sheet. The stacking of these layers results in either a 1:1 structure (one tetrahedral and one octahedral layer) or a 2:1 structure (two tetrahedral layers flanking one octahedral layer). The structural arrangement directly affects clay plasticity, ion-exchange capacity, and response to heat treatment (Nascimento, 2021).

During the drying and firing process, several chemical and physical transformations occur. Initially, free water evaporates at around 100°C, followed by the loss of chemically bound water between 350°C and 500°C. This dehydroxylation marks an irreversible chemical change in which clay minerals are transformed into a more compact and brittle material. Around 573°C, quartz inversion takes place, where α-quartz transitions to β-quartz, causing a temporary volume expansion. At higher temperatures (approximately

900–1000°C), organic and inorganic impurities such as carbonates and sulfates are decomposed, while vitrification begins—a process in which the clay matrix partially melts to form a glass-like phase that strengthens and densifies the material (Kuwayama et al., 2015).

The formation of mullite ($3Al_2O_3 \cdot 2SiO_2$), a needle-like aluminum silicate crystal, plays a crucial role in enhancing the mechanical strength and cohesion of the fired clay body. The extent of mullite crystallization depends on the firing temperature and composition of the clay mixture. Red clays rich in iron oxides typically vitrify at approximately 1000°C and melt around 1250°C, while purer kaolin clays require temperatures exceeding 1800°C to achieve similar transformations.

By combining different types of clay—such as kaolinite, montmorillonite, and illite—along with non-plastic additives like quartz and feldspar, artisans can tailor the thermal and mechanical properties of the ceramic body for optimal performance. These practices illustrate how local craftsmanship reflects an intuitive understanding of chemical thermodynamics, phase transformation, and materials engineering principles long before such processes were formally defined in modern science.

Thus, the traditional Majalengka clay roof tile production exemplifies a culturally embedded practice of material science, where indigenous knowledge of soil composition and heat treatment aligns with key chemical principles of hydration, oxidation, and vitrification. Such contexts provide rich opportunities for the educational reconstruction of chemistry learning, linking students' local experiences with formal concepts of inorganic chemistry and solid-state transformations.

4. Cirebon Batik

The traditional batik craft of Cirebon represents a sophisticated intersection between cultural artistry and applied chemistry. Three critical components define the batik-making process: the fabric substrate, the wax resist, and the dyeing agents. The type of fabric used—whether natural fibers such as cotton or silk, or synthetic polymers—directly influences dye absorption and chemical reactivity. Natural fibers tend to form stronger molecular interactions with most traditional dyes, whereas synthetic fibers often require specialized dyeing agents to achieve comparable fixation (Negi, 2025).

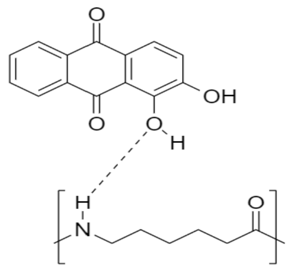

Figure 4. The hydrogen atoms in the fabric and the oxygen atoms in the dye form hydrogen bonds

The wax-resist process involves covering specific areas of the fabric with melted wax (commonly composed of beeswax, rosin, and vegetable oils) to prevent dye penetration. The molecular adhesion between wax and fiber occurs through hydrogen bonding and dispersion forces, ensuring selective coloration during subsequent dyeing stages. Figure 4 schematically illustrates hydrogen bonding between hydroxyl groups on cellulose fibers and oxygen atoms on dye molecules, explaining how dye molecules adhere to fabric surfaces.

Chemically, batik dyeing in Cirebon primarily employs two classes of dyes: naphthol dyes and indigosol dyes, each involving distinct reaction mechanisms. Naphthol dyes are generally water-insoluble and must undergo substitution reactions to form water-soluble sodium salts. When sodium hydroxide (NaOH) reacts with the hydroxyl group of naphthol, it forms the more soluble naphtholate ion, as shown in Equation (1):

$$D\text{-}OH + NaOH \rightarrow D - O - Na$$

Subsequent immersion in a diazonium solution produces the desired azo dye through a coupling reaction, yielding a stable chromophore that binds covalently to the fiber (Hunger, 2003):

$$Ar\text{-}NH_2 \xrightarrow{HCl + NaNO2,\ 5°C} Ar - N = N^+ Cl^-$$

$$Ar - N = N^+ Cl^- + D - O - Na \rightarrow Ar - N = N - O - D \text{ (lake)}$$ (Chakraborty et al., 2013)

This sequence represents a classic azo coupling mechanism, where the diazonium ion reacts with the activated aromatic compound to form a colored azo linkage (–N=N–).

In contrast, indigosol dyes operate through a redox mechanism. These dyes are initially soluble in their reduced (leuco) form and become insoluble only after oxidation. The process begins with hydrolysis of the sulfur ester group in acidic conditions, followed by oxidation using sodium nitrite ($NaNO_2$) to regenerate the insoluble pigment that imparts color to the fabric. This mechanism is depicted in Figure 5, representing the oxidation pathway of *Indigosol Yellow V* from its leuco form to its oxidized chromophore (Sérgio Seixas De Melo, 2017).

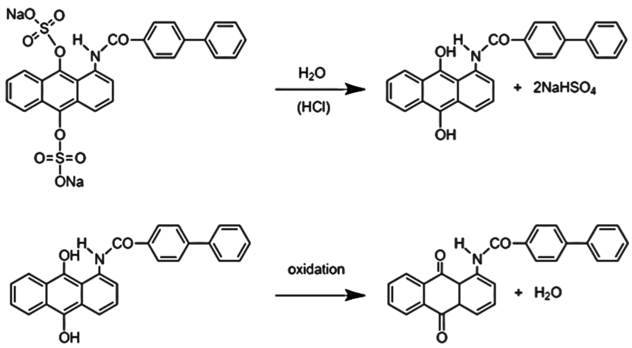

Figure 5. Oxidation Process of Indigosol Yellow V

From a chemical standpoint, both dyeing systems illustrate fundamental concepts of acid–base reaction, nucleophilic substitution, oxidation–reduction, and intermolecular interaction. The traditional wax-resist dyeing process also provides a tangible representation of chemical selectivity, reaction kinetics, and thermodynamic stability in color fixation.

From an educational perspective, the Cirebon batik process exemplifies how ethnochemical knowledge can be reconstructed within the MER framework. Through the didactic reduction of complex dye chemistry into contextually meaningful phenomena, students can connect cultural craftsmanship with core topics in organic chemistry, intermolecular bonding, and reaction mechanisms. This integration reinforces both conceptual understanding and cultural appreciation, aligning with the broader goals of culturally responsive science education.

5. Indramayu Shadow Puppetry

The traditional shadow puppet theatre (*wayang kulit*) of Indramayu represents one of the most enduring forms of Javanese–Sundanese court-derived performing arts. The term *wayang* is believed to originate from the Old Javanese phrase *Ma Hyang*, meaning "toward the divine," reflecting its spiritual association with ancestral and cosmic forces. The performance traditionally takes place behind a translucent screen (*kelir*), allowing audiences to view only the moving silhouettes—a symbolic metaphor for the relationship between the physical and the metaphysical worlds (Irma & Abdul Jalil, 2023).

In Indramayu, shadow puppet performances continue to play a vital role in community life, particularly during cultural ceremonies such as *Mapag Sri* (harvest welcoming), *Ngarot* (village thanksgiving), *Nadran* (sea offering), and *Ruwatan* (spiritual cleansing). These performances serve both as moral instruction and social cohesion mechanisms, illustrating the integration of cultural identity and artistic expression.

From a material science perspective, buffalo hide is the preferred medium for crafting *wayang kulit* due to its low lipid content, high tensile strength, and resistance to warping. Compared to cowhide, which contains higher levels of natural oils and thus requires prolonged drying, buffalo hide can dry within 4–5 days under sunlight exposure. Chemically, raw animal hide consists predominantly of water (≈65%), protein (≈33%), fat (≈2%), and mineral components (≈0.5%)(Samidurai et al., 2022). The key structural protein is collagen, a fibrous molecule that contributes approximately 29% of the total protein content and provides elasticity and mechanical resilience. Other fibrous proteins include keratin and elastin, while non-fibrous proteins such as albumin, globulin, and mucin are present in smaller quantities.

The integrity and flexibility of buffalo hide arise from the triple-helical collagen structure, in which three polypeptide chains form hydrogen bonds stabilized by glycine–proline–hydroxyproline sequences (Ruiz-Rodriguez et al., 2021). During the preparation process, the raw hide undergoes controlled dehydration and defatting, processes that alter its molecular configuration through partial denaturation of collagen fibers. Treatments such as lime soaking ($Ca(OH)_2$) or hot-water immersion facilitate the breakdown of hair keratin and residual tissue, effectively exposing the collagen matrix. This process is chemically similar to alkaline hydrolysis, where hydroxide ions disrupt peptide cross-links, allowing for mechanical scraping and refinement of the hide's surface.

Following mechanical thinning, the hide is tanned and polished, often using natural abrasives and plant-based oils to restore flexibility. The tanning process—though milder than industrial chrome tanning—nonetheless involves cross-link formation between collagen and polyphenolic compounds from plant extracts, enhancing resistance to microbial decay. This mechanism parallels the use of vegetable tannins, such as gallic and ellagic acids, which form hydrogen-bonded complexes with amide groups in collagen (Brăzdaru et al., 2022).

The artistic phase, known as *sungging*, involves engraving, perforation, and multistage pigmentation using traditional organic dyes derived from natural minerals and plant extracts. The painting sequence follows a systematic layering of base coat (*andasari*), coloring (*mecna*), contouring (*angulat-ulati*), and finishing (*angadus*). From a chemical viewpoint, this stage demonstrates the principles of light absorption, pigment binding, and surface chemistry, as pigments adhere to the treated collagen via ionic and hydrogen bonding.

Thus, the Indramayu shadow puppet tradition exemplifies a convergence of cultural craftsmanship and material chemistry, integrating organic macromolecular processes (denaturation, hydrolysis, cross-linking) within an artistic context. Within MER, this cultural practice can be didactically reframed as an entry point for learning about protein chemistry, biopolymer modification, and surface interaction phenomena. The didactic reduction of such ethnocultural material provides chemistry students with a contextualized understanding of structure–function relationships in biological materials while reinforcing appreciation for Indonesia's tangible cultural heritage.

High school chemistry concepts related to local wisdom contexts

Based on the scientific structure analysis conducted on the aforementioned local wisdom contexts, several aspects related to chemistry concepts were identified. After determining which aspects were associated with chemical concepts, the next step was to analyze their alignment with the existing curriculum structure. This step served as the foundation for the reconstruction process, including didactic reduction.

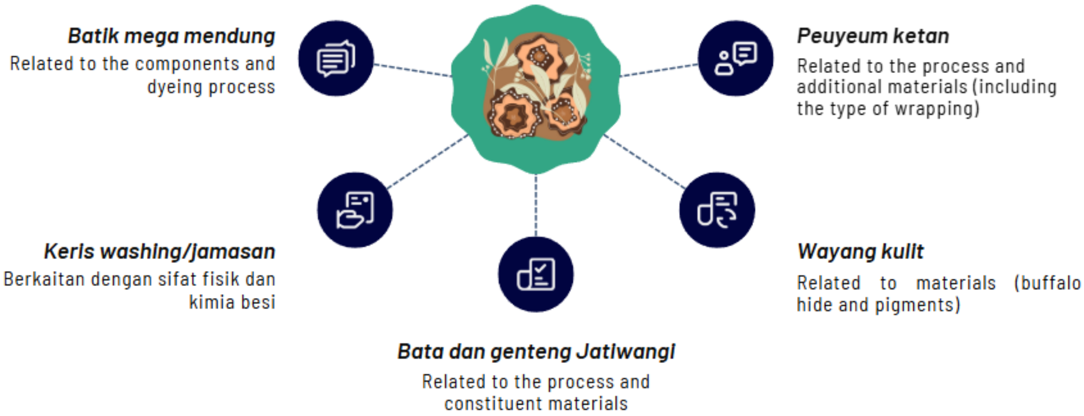

Figure 6. Aspects of Local Wisdom Related to Chemistry Concepts

In this analysis, the chemistry learning outcomes of the *Kurikulum Merdeka* were used as the reference framework to assess the compatibility between the scientific structures of the local wisdom contexts and high school chemistry learning. Table 3 below presents the formulation of the *Learning Outcomes* and *Learning Objective Flow* for high school chemistry that served as the basis for analyzing the alignment between the scientific structures of local wisdom contexts and high school chemistry concepts.

Table 3. Formulation of Learning Outcomes and Learning Objective Flow of High School Chemistry

Phase	Learning Outcomes	Learning Objective Flow
E	Students are able to respond to global issues and actively participate in problem-solving. This ability includes identifying, analyzing ideas, designing solutions, making decisions, and communicating them in the form of simple projects or visual simulations using available technological applications related to alternative energy, global warming, environmental pollution, nanotechnology, biotechnology, chemistry in everyday life, utilization of natural materials and waste, as well as pandemics caused by viral infections.	The nature of chemistry, scientific methods, and laboratory safety concepts; Theories of atomic development; Chemical waste and natural material analysis; The importance of green chemistry and environmental pollution solutions; Basic chemical laws and their applications; Chemical equations and their applications; Atomic structure and its applications in nanotechnology; Electron configuration relationships and periodic table element positions.
F	Students are able to observe, investigate, and explain everyday phenomena using scientific principles to clarify chemical concepts in daily life; apply mathematical operations in chemical calculations; study properties, structures, and particle interactions in forming various compounds; understand and explain energy aspects, rates, and equilibrium of chemical reactions; apply acid-base concepts in daily life; utilize chemical energy transformations in daily life; and understand organic chemistry.	Hydrocarbons and petroleum; Basic concepts of enthalpy change; Types and determination of enthalpy reactions; Collision theory and factors affecting reaction rate; Reaction rate; Chemical equilibrium; Shifts in chemical equilibrium; Acid-base solutions; Salt hydrolysis; Buffer solutions; Acid-base titration; Colloid systems; Colligative properties of solutions;

Phase	Learning Outcomes	Learning Objective Flow
		Redox reactions; Derivatives of alkanes; Benzene and its derivatives; Macromolecules.

The chemical concepts identified through the scientific structure analysis were then further examined based on the formulation of the Learning Outcomes and Learning Objective Flow as presented in Table 3. To ensure the credibility and dependability of the analysis results, a peer examination was conducted by three lecturers with academic backgrounds in chemistry education and pure chemistry. This peer review aimed to assess the alignment between aspects of local wisdom containing chemical concepts and the learning objective flow of high school chemistry. Based on the results of this review, a mapping of the relationships between local wisdom contexts and chemical concepts was developed, as shown in Figure 7 below.

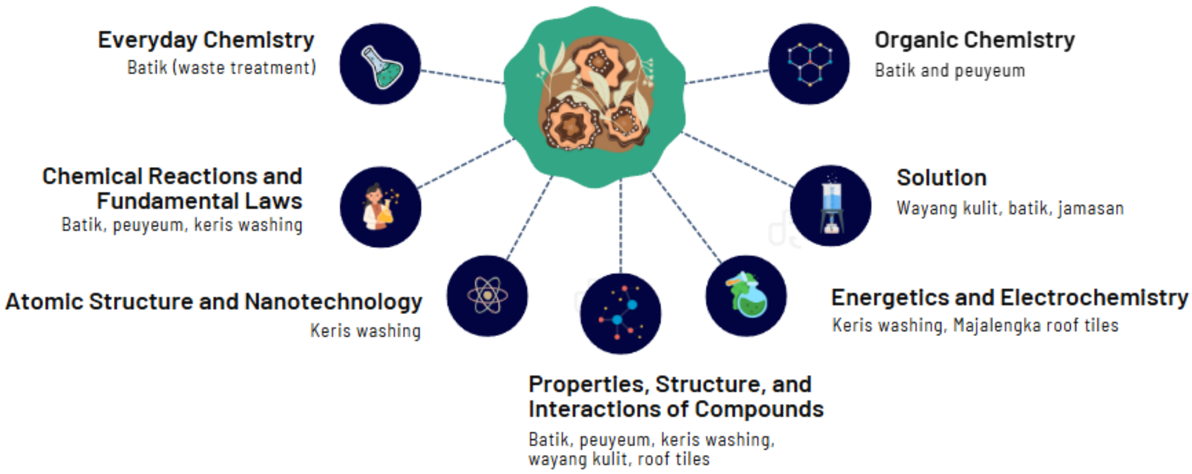

Figure 7. Map of Local Wisdom and Chemistry Concepts Relationship

The mapping in Figure 7 also reveals a clear variation in the distribution of chemistry concepts represented across the five identified cultural practices. Chemical reactions and fundamental laws, properties–structure–interactions of compounds, and organic chemistry emerge as the most dominantly represented conceptual domains. These concepts appear across multiple contexts—particularly batik production, *peuyeum* fermentation, *jamasan*, and *wayang kulit* processing—because these cultural practices inherently involve observable chemical transformations such as oxidation–reduction processes, organic compound reactions, fermentation mechanisms, dye–fiber interactions, and changes in the physical and chemical properties of materials. Their strong presence indicates that these domains provide substantial potential for developing contextual chemistry learning activities grounded in real cultural phenomena.

In contrast, atomic structure and nanotechnology is the least represented domain, appearing explicitly only in the context of *keris* washing, where processes related to metal microstructure, surface oxidation, and corrosion resistance can be conceptually linked to atomic-scale interactions. However, these underlying principles are not directly observable within everyday cultural practices, making their representation more limited compared to other domains that involve more tangible material transformations.

Similarly, everyday chemistry, energetics and electrochemistry appear in fewer contexts. Everyday chemistry is primarily represented through *batik* waste treatment, while energetics and electrochemistry appear notably in *keris* washing and Majalengka roof tile production, both of which involve energy changes, heating processes, and electrochemical aspects of metal oxidation. Although these concepts are present, their distribution is narrower because only certain practices exhibit clear indicators of energy changes or redox behavior suitable for instructional reconstruction.

Overall, this distribution pattern suggests that chemical reactions, molecular structure, and organic processes provide the richest and most accessible entry points for contextual chemistry learning in the Ciayumajakuning region. Meanwhile, atomic-level and nanotechnology-related concepts require more careful pedagogical reconstruction, as they are embedded less explicitly within cultural practices. These insights are crucial for guiding the prioritization of concept selection in the subsequent development of contextual and curriculum-aligned chemistry learning materials.

Through this mapping, researchers are able to determine the depth of content that can be taught, select relevant phenomena for classroom activities, and design learning experiences that integrate cultural relevance with scientific rigor. Consequently, the mapping not only reveals the pedagogical potential of Ciayumajakuning's local wisdom but also guides the systematic development of contextual learning resources that support meaningful, coherent, and curriculum-aligned chemistry education. By connecting cultural practices and scientific concepts, it enables meaningful learning that grounds abstract chemistry content within students' everyday experiences. Ethnoscience-based learning, in this regard, bridges local wisdom and scientific knowledge, making chemistry more relevant, contextual, and accessible for students. Previous studies indicate that contextual learning embedded with ethnoscience improves students' conceptual understanding, scientific literacy, and critical thinking skills, as well as their engagement and motivation in science learning (Dewi et al., 2019; Primadianningsih et al., 2023; Sari et al., 2023). Therefore, utilizing contextual learning combined with ethnoscience is particularly appropriate for reconstructing chemistry learning from the cultural practices prevalent in Ciayumajakuning.

CONCLUSION AND RECOMMENDATIONS

This study confirms that the Model of Educational Reconstruction (MER) effectively bridges local wisdom and formal chemistry education. The reconstruction of five Ciayumajakuning cultural contexts—*batik*, *wayang kulit*, *jamasan*, *bata dan genteng Jatiwangi*, and *peuyeum ketan*—revealed rich chemical principles aligned with the high school curriculum. Although the contextual–conceptual distribution was uneven, the analysis demonstrates strong potential for culturally responsive and meaningful chemistry learning. It is recommended that teachers and curriculum designers integrate these contexts through didactic reduction and curriculum alignment. Future research should focus on developing validated teaching materials and evaluating their impact on students' conceptual understanding, scientific literacy, and cultural awareness.

REFERENCES

Aldiansyah, A., Pasa, J. I., Muttaqin, M. R., Awaliyah, N. N., & Erika, F. (2023). Literatur review: keterkaitan pembelajaran kimia terhadap pendekatan etnokimia di indonesia. *CHEDS: Journal of Chemistry, Education, and Science*, *7*(2), 238–246. https://doi.org/10.30743/cheds.v7i2.8416

Andriani, M., Muhali, M., & Dewi, C. A. (2019). Pengembangan modul kimia berbasis kontekstual untuk membangun pemahaman konsep siswa pada materi asam basa. *Hydrogen: Jurnal Kependidikan Kimia*, *7*(1), 25. https://doi.org/10.33394/hjkk.v7i1.1653

Brăzdaru, L., Staicu, T., Albu Kaya, M. G., Chelaru, C., Ghica, C., Cîrcu, V., Leca, M., Ghica, M. V., & Micutz, M. (2022). 3D porous collagen matrices—a reservoir for in vitro simultaneous release of tannic acid and chlorhexidine. *Pharmaceutics*, *15*(1), 76. https://doi.org/10.3390/pharmaceutics15010076

Cahyana, Y., & Adiyanti, T. (2021). Flavonoids as antidiabetic agents. *Indonesian Journal of Chemistry*, *21*(2), 512. https://doi.org/10.22146/ijc.58439
Chakraborty, S., Basak, B., Dutta, S., Bhunia, B., & Dey, A. (2013). Decolorization and biodegradation of congo red dye by a novel white rot fungus Alternaria alternata CMERI F6. *Bioresource Technology*, *147*, 662–666. https://doi.org/10.1016/j.biortech.2013.08.117
Chauhan, D. S., Quraishi, M. A., Sorour, A. A., & Verma, C. (2022). A review on corrosion inhibitors for high-pressure supercritical CO2 environment: Challenges and opportunities. *Journal of Petroleum Science and Engineering*, *215*, 110695. https://doi.org/10.1016/j.petrol.2022.110695
Das, B. M., Khing, K. H., & Shin, E. C. (1998). Stabilization of weak clay with strong sand and geogrid at sand-clay interface. *Transportation Research Record: Journal of the Transportation Research Board*, *1611*(1), 55–62. https://doi.org/10.3141/1611-07
Dewi, C. A., Khery, Y., & Erna, M. (2019). An ethnoscience study in chemistry learning to develop scientific literacy. *Jurnal Pendidikan IPA Indonesia*, *8*(2). https://doi.org/10.15294/jpii.v8i2.19261
Duit, R., Gropengießer, H., Kattmann, U., Komorek, M., & Parchmann, I. (2012). The model of educational reconstruction – a framework for improving teaching and learning science1. in d. jorde & j. dillon (eds.), *Science Education Research and Practice in Europe* (pp. 13–37). SensePublishers. https://doi.org/10.1007/978-94-6091-900-8_2
Fiqry, R., & Agustinasari, A. (2025). Lanskap global etnosains dalam pendidikan: tinjauan prisma-scr terhadap literatur scopus (2000-2025) sebagai jembatan pengetahuan budaya dan pembelajaran sains modern. *JagoMIPA: Jurnal Pendidikan Matematika Dan IPA*, *5*(2), 729–744. https://doi.org/10.53299/jagomipa.v5i2.2056
Gobbetti, M., Cagno, R. D., & De Angelis, M. (2010). Functional microorganisms for functional food quality. *Critical Reviews in Food Science and Nutrition*, *50*(8), 716–727. https://doi.org/10.1080/10408398.2010.499770
Harmayani, E., Santoso, U., & Gardjito, M. (2017). *Makanan tradisional Indonesia* (Cetakan kedua). Gadjah Mada University Press.
Irma, I., & Abdul Jalil, A. (2023). Wayang potel: (hiburan religi masyarakat desa cikedung kabupaten indramayu). *Khulasah : Islamic Studies Journal*, *5*(2), 32–44. https://doi.org/10.55656/kisj.v5i2.103
Kuwayama, M., Gandhi, G., Kagalwala, S., & Ramani, R. (2015). Vitrification: an overview. in g. allahbadia, m. kuwayama, & g. gandhi (eds.), *Vitrification in Assisted Reproduction* (pp. 1–7). Springer India. https://doi.org/10.1007/978-81-322-1527-1_1
Lu, J., Zheng, J., Zhao, D., Xu, Y., & Chen, S. (2025). The Effect of ethanol on the compound thresholds and aroma perception in chinese baijiu. *Molecules*, *30*(4), 933. https://doi.org/10.3390/molecules30040933
Mustafa, Z., Su Ling, L., & Yusoff, N. E. (2024). Culturally responsive science pedagogy through malay bardic stories. *International Journal of Creative Future and Heritage (TENIAT)*, *12*(2), 47–56. https://doi.org/10.47252/teniat.v12i2.1257
Nascimento, G. M. do (Ed.). (2021). *Clay and Clay Minerals*. IntechOpen.
Negi, A. (2025). Environmental impact of textile materials: challenges in fiber–dye chemistry and implication of microbial biodegradation. *Polymers*, *17*(7), 871. https://doi.org/10.3390/polym17070871
Nuraida, L. (2015). A review: Health promoting lactic acid bacteria in traditional Indonesian fermented foods. *Food Science and Human Wellness*, *4*(2), 47–55. https://doi.org/10.1016/j.fshw.2015.06.001
Petchey, S. E., & Niebert, K. (2021). Educational reconstruction as a model for designing science teaching at university. *Herausforderung Lehrer*innenbildung - Zeitschrift zur*

Konzeption, *Gestaltung und Diskussion*, 193-212 Seiten. https://doi.org/10.11576/HLZ-2699

Primadianningsih, C., Sumarni, W., & Sudarmin, S. (2023). Systematic literature review: analysis of ethno-stem and student's chemistry literacy profile in 21st century. *Jurnal Penelitian Pendidikan IPA*, *9*(2), 650–659. https://doi.org/10.29303/jppipa.v9i2.2559

Qian, B., Hou, B., & Zheng, M. (2013). The inhibition effect of tannic acid on mild steel corrosion in seawater wet/dry cyclic conditions. *Corrosion Science*, *72*, 1–9. https://doi.org/10.1016/j.corsci.2013.01.040

Rofiqoh, I., Suaidah, H. L., & Kinanti, A. R. (2022). *Analisis Kualitas Tape Ketan dengan Berbagai Alternatif Bahan Pembungkus*.

Ruiz-Rodriguez, L., Loche, P., Hansen, L. T., Netz, R. R., Fratzl, P., Schneck, E., Blank, K. G., & Bertinetti, L. (2021). Sequence-specific response of collagen-mimetic peptides to osmotic pressure. *MRS Bulletin*, *46*(10), 889–901. https://doi.org/10.1557/s43577-021-00138-9

Sakmawati, S., Muti'ah, M., & Hadisaputra, S. (2023). Pengembangan modul pembelajaran kimia sma/ma berbasis kontekstual pada pokok bahasan larutan elektrolit dan nonelektrolit. *Chemistry Education Practice*, *6*(2), 310–315. https://doi.org/10.29303/cep.v6i2.3738

Samidurai, S., Khambhaty, Y., & Alagamuthu, T. S. (2022). Bio-preservation of raw hides/skins: A review on greener substitute to conventional salt curing. *Environmental Science and Pollution Research*, *29*(43), 64513–64535. https://doi.org/10.1007/s11356-022-22027-7

Sari, F. P., Maryati, M., & Wilujeng, I. (2023). Ethnoscience studies analysis and their integration in science learning: literature review. *Jurnal Penelitian Pendidikan IPA*, *9*(3), 1135–1142. https://doi.org/10.29303/jppipa.v9i3.2044

Selhub, E. M., Logan, A. C., & Bested, A. C. (2014). Fermented foods, microbiota, and mental health: Ancient practice meets nutritional psychiatry. *Journal of Physiological Anthropology*, *33*(1), 2. https://doi.org/10.1186/1880-6805-33-2

Sérgio Seixas De Melo, J. (2017). The molecules of colour. In A. Albini, E. Fasani, & S. Protti (Eds.), *Photochemistry* (Vol. 45, pp. 68–100). Royal Society of Chemistry. https://doi.org/10.1039/9781788010696-00068

Silva, A. T. M. D., Silva, R. A. D., & Neves, R. F. D. (2024). The model of educational reconstruction: an instructional design in science education. *Revista de Ensino, Educação e Ciências Humanas*, *25*(3), 588–594. https://doi.org/10.17921/2447-8733.2024v25n3p588-594

Sutrisno, H., Wahyudiati, D., & Louise, I. S. Y. (2020). Ethnochemistry in the chemistry curriculum in higher education: exploring chemistry learning resources in sasak local wisdom. *Universal Journal of Educational Research*, *8*(12A), 7833–7842. https://doi.org/10.13189/ujer.2020.082572

Syazali, M., & Umar, U. (2022). Peran kebudayaan dalam pembelajaran ipa di indonesia: studi literatur etnosains. *Jurnal Educatio FKIP UNMA*, *8*(1), 344–354. https://doi.org/10.31949/educatio.v8i1.2099

Wahyuningsih, E. A., Irmanda, L., Aji, Y. W. K., Hidayat, R., & Anindita, N. S. (2023). *Pengaruh lama fermentasi, penambahan ragi dan konsentrasi gula pada tape ketan*. *1*.

Wardani, N. K., Susanti, R., Iswari, R. S., & Rusminingsih, A. (2022). *Pengaruh Lama Perendaman dan Jenis Pembungkus terhadap Kadar Etanol Tape Ketan*.

Weni Mandasari, Yulizar Prawiranti, Sofi Siti Shofiyah, Muftiah Yasi Dwi Wahyuni, Fitriyan Kurnia, Atika Wulandari Putri, Dodi, Yudith Evametha Vitranilla, & Weny Ramadhania. (2025). Inovasi produk kimia ramah lingkungan: sabun herbal dari limbah kulit nanas sebagai media edukasi siswa man 2 pontianak. *JURPIKAT (Jurnal*

Pengabdian Kepada Masyarakat), *6*(3), 1478–1487. https://doi.org/10.37339/jurpikat.v6i3.2450
Xie, D., Sun, Y., & Lei, Y. (2022). Effect of glucose levels on carbon flow rate, antioxidant status, and enzyme activity of yeast during fermentation. *Journal of the Science of Food and Agriculture*, *102*(12), 5333–5347. https://doi.org/10.1002/jsfa.11887
Yanto, N., Nur Indah Sari, & Yahya. (2025). Exploring scientific literacy in science classrooms: a literature study. *Venn: Journal of Sustainable Innovation on Education, Mathematics and Natural Sciences*, *4*(3), 164–173. https://doi.org/10.53696/venn.v4i3.292
Yusmar, F., & Fadilah, R. E. (2023). Analisis rendahnya literasi sains peserta didik indonesia: hasil pisa dan faktor penyebab. *LENSA (Lentera Sains): Jurnal Pendidikan IPA*, *13*(1), 11–19. https://doi.org/10.24929/lensa.v13i1.283