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Scientific Reconstruction of Local Wisdom for Contextual Chemistry Education: An Ethnographic Study on *Peuyeum Ketan*, *Jamasan Keris*, and Traditional Roof Tiles

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Abstract: This ethnographic study integrates the Model of Educational Reconstruction (MER) to develop contextual chemistry education based on local wisdom in Ciayumajakuning, Indonesia. We systematically reconstructed three traditional practices: *peuyeum ketan* fermentation, *jamasan keris*, and *genteng Jatiwangi* production. Through eight-month participatory observation documenting production cycles, we captured practitioners' tacit knowledge and actual production processes. Student surveys (n=90) with Rasch analysis revealed varying instrument reliability: *jamasan keris* adequate (0.77), *peuyeum ketan* low (0.43), *genteng* very low (0.28). Item analysis identified tannin's corrosion inhibition mechanism as exceptionally difficult (2.73 logits), revealing students view chemical protection through mechanical rather than chemical lens. Analysis demonstrates how traditional techniques embody chemical principles: enzymatic pathways, redox reactions, and thermochemical transformations. Systematic triangulation validates traditional knowledge authenticity while identifying pedagogical interventions. Cross-context findings reveal students consistently interpret chemical transformations as physical processes, struggle connecting molecular and macroscopic levels, and compartmentalize abstract knowledge from cultural applications.

Keywords: Contextual Learning, Local Wisdom, Model of Educational Reconstruction, Ethnography, Chemistry Education

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1. Introduction

Contextual learning has been identified as a potential remedy for students' lack of interest and the limited relevance of scientific content to real-life situations (Pernaa et al., 2022; Sarwinda et al., 2020). A meta-analysis of 66 studies has shown that contextual approaches not only foster positive student attitudes but also motivate them to engage more deeply with science subjects (De Jong, 2018). Despite the extensive research on contextual approaches in education, their relevance persists in contemporary educational research topics, including STEM education (Collins, 2018), scientific literacy (Chen & Osman, 2017), and the Sustainable Development Goals (Oliveira et al., 2019). The integration has proven effective in enhancing students' critical thinking skills through meaningful and relevant learning experiences.

In Indonesia, the potential for developing contextual chemistry education lies in integrating local wisdom. The Ciayumajakuning region (Cirebon, Indramayu, Majalengka, Kuningan) has been chosen as the research locus due to its unique convergence of Sundanese and Javanese cultures, which has given rise to local wisdom practices such as Cirebon *batik*. The *batik*-making process, for instance, involves the oxidation reaction of indigosol dyes (Anugrah & Kartimi, 2022). Regrettably, previous studies have indicated that efforts to integrate local culture into chemistry curricula are often superficial. Although attempts have been made to link local culture with chemistry topics, these approaches frequently lack an in-depth scientific and pedagogical analysis. This deficiency may lead to misconceptions and hinder the achievement of practical learning objectives (Utami & Astutik, 2025). Consequently, a framework that bridges scientific accuracy and cultural significance is essential.

Our preliminary study (Anugrah et al., 2025) addressed this gap by applying the Model of Educational Reconstruction (MER) framework to systematically map local wisdom contexts in the Ciayumajakuning region. Through survey methodology involving 17 respondents and comprehensive literature review, that study identified five contexts with strong chemical relevance: *batik* Cirebon, *wayang kulit*, *jamasan keris*, Jatiwangi traditional roof tile, and *peuyeum ketan*. Each was analyzed for scientific content structure and mapped against the *Kurikulum Merdeka* learning outcomes, demonstrating that these practices collectively span seven chemistry domains—from organic chemistry to electrochemistry.

However, that preliminary mapping study had inherent methodological limitations. As a survey-based investigation relying primarily on secondary sources, it could not access the tacit, embodied knowledge that practitioners develop through years of experience but may not fully articulate (Polanyi, 1966; Turner, 2022). Traditional practices involve sensory judgments (recognizing fermentation readiness by smell), temporal expertise (knowing when firing temperatures require adjustment), and procedural coordination that are invisible to literature review or brief interviews. Additionally, the study did not empirically investigate students' actual preconceptions regarding these cultural contexts, relying instead on general assumptions about conceptual difficulties. Without diagnostic data on learners' thinking, instructional design remains speculative rather than evidence-based. These limitations motivated the current research.

This study adopts the MER as its theoretical framework. MER is selected due to its three key components—(1) analysis of scientific content structure (e.g., enzymatic reactions in *peuyeum*), (2) investigation of students' understanding (e.g., perceptions of fermentation), and (3) instructional evaluation—which enable the multidimensional reconstruction of cultural contexts (Anugrah, 2021b, 2021a). This model has the advantage of emphasizing students' prior knowledge, ensuring that the constructed learning contexts accommodate students' needs for relevant concepts (Ekawati, 2018). The current study conducts intensive ethnographic reconstruction of three strategically selected contexts: *peuyeum ketan* (fermented glutinous rice), *jamasan keris* (ceremonial dagger cleansing), and *genteng* Jatiwangi (traditional roof tile production).

The research novelty lies in methodological integration and empirical depth. First, we employ systematic participant observation as the primary data collection method—documenting actual practices over eight months rather than relying on practitioner self-reports. Second, we explicitly investigate students' preconceptions (n=90), providing empirical diagnostic data that culturally-grounded instruction must address. Third, we demonstrate systematic triangulation across observation, practitioner explanations, and scientific literature, ensuring both cultural authenticity and scientific accuracy. Fourth, we extend MER application beyond content mapping (Component 1) to comprehensive investigation of learners' conceptions (Component 2), providing empirical foundation for subsequent instructional design.

This study extends our preliminary mapping work by addressing three interconnected research questions: 1) How do expert practitioners' tacit knowledge and empirical quality indicators align with formal chemical principles underlying traditional practices in *peuyeum ketan* production, *jamasan keris* rituals, and *genteng* Jatiwangi manufacturing? 2) What preconceptions and alternative conceptions do high school students hold regarding the chemical processes underlying these three local wisdom contexts, and how do these differ from scientific explanations? 3) How can ethnographic data on practitioners' embodied expertise and students' culturally-shaped conceptions inform the pedagogical reconstruction of local wisdom into effective, culturally-sustaining chemistry learning materials? These questions operationalize MER's first two components—content structure analysis and investigation of learners' perspectives—within an ethnographic framework that prioritizes depth, cultural authenticity, and pedagogical applicability.

2. Method

Research Design

This study employs observation-centered ethnographic methodology integrated with the Model of Educational Reconstruction (MER) framework. Building on our preliminary mapping study (Anugrah et al., 2025) that identified five local wisdom

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contexts through survey and literature review, the current research conducts systematic reconstruction of three strategically selected contexts: *peuyeum ketan*, *jamasan keris*, and *genteng* production. These contexts were selected based on: (1) representational diversity across chemistry domains (biochemistry, electrochemistry, and material science), (2) accessibility of expert practitioners, and (3) relevance to student experiences.

The research design prioritizes direct observation of actual practices as the primary data source, addressing a fundamental limitation of survey-based approaches: tacit, embodied knowledge that practitioners demonstrate but may not fully articulate (Polanyi, 1966). The study operationalizes MER's first two components—content structure analysis and investigation of learners' perspectives—through ethnographic fieldwork and student surveys conducted over eight months (January-August 2024) in the Ciayumajakuning region, West Java, Indonesia.

Participants

Three categories of participants were involved: master practitioners (primary informants), high school students (preconception survey), and validation experts. Due to declining numbers of expert practitioners and the specialized nature of these traditions, one master practitioner per context was recruited through purposive sampling with assistance from local cultural authorities. Selection criteria included minimum 20 years' experience, community recognition as expert, and willingness for extended research engagement.

All practitioners provided informed consent. Pseudonyms (Mr. A, Mr. B, and Mr. C) are used for anonymity. Additionally, ninety high school students from three schools in Ciayumajakuning participated in preconception surveys after obtaining informed consent.

Data Collection

Participant Observation (Primary Data Source)

Systematic participant observation constituted the primary methodology. The researcher documented production and rituals across the three contexts, accumulating over 120 hours of direct observation. Observation protocols included structured, time-stamped field notes documenting procedures, materials, measurements, observable changes, and practitioner decisions. Photographic and video documentation (with permission) captured key stages and technical procedures. Real-time clarification questions during observation elicited practitioner rationales and quality indicators.

Practitioner Interviews (Supplementary Data)

Each practitioner participated in 6-8 semi-structured interviews (45-90 minutes each) conducted during or immediately after observation sessions. Interviews elicited rationales for techniques, tacit knowledge indicators ("How do you know when it's ready?"), quality criteria, troubleshooting strategies, and knowledge transmission histories. All interviews were audio-recorded with consent and transcribed verbatim.

Student Preconception Survey (Diagnostic Data)

To inform instructional design (MER Component 2), students completed multiple- choice instruments assessing understanding of chemical processes underlying three local wisdom contexts: *jamasan keris*, *peuyeum ketan* and *genteng* Majalengka. Each instrument contained items designed to probe students' conceptual understanding, preconceptions, and potential misconceptions related to the chemical principles underlying each cultural practice. Surveys were administered in school settings (May 2024) with 30-45 minutes completion time. Ninety high school students (Grade 12) from three schools in Ciayumajakuning participated after obtaining informed consent. Response data were analyzed using Rasch measurement model to assess instrument quality (item reliability, separation indices, and fit statistics) and identify misconception patterns through item difficulty analysis and distractor effectiveness evaluation.

Data Analysis and Triangulation

Observation field notes were analyzed through iterative coding: (1) descriptive coding—documenting procedures and sequences; (2) process coding—identifying techniques and timing; (3) analytical coding—connecting observed phenomena to chemical principles. Interview transcripts underwent thematic analysis to identify patterns in practitioner knowledge. Student responses were coded to identify common misconceptions and alternative conceptions.

To ensure credibility, we employed systematic triangulation at five levels:

1. Within-method triangulation: Comparing observations across multiple production cycles (3-6 per context) to distinguish stable traditional knowledge from situational adaptations.
2. Between-method triangulation: Comparing observed practices with practitioner explanations to identify tacit vs. explicit knowledge.
3. Data source triangulation: Comparing observed practices and practitioner explanations with scientific literature on fermentation chemistry, corrosion science, and ceramic materials.
4. Expert validation: Three chemistry education experts reviewed analytical codes for scientific accuracy; one cultural anthropologist and two local cultural authorities verified cultural authenticity; experts confirmed curriculum alignment with *Kurikulum Merdeka* learning outcomes.

Community validation: Informal discussions with customers and community members confirmed that observed practices align with broader traditions.

3. Result and Discussion

Result

The findings are organized into three components corresponding to MER's analytical framework: (1) scientific content structure underlying each traditional

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practice, (2) practitioners' tacit knowledge and quality indicators, and (3) students' preconceptions and misconceptions.

Scientific Content Structure of Traditional Practices

Peuyeum ketan: Enzymatic Fermentation and Carbohydrate Metabolism

Peuyeum ketan production involves complex biochemical transformations driven by microbial consortia in traditional fermentation starter (*ragi*). Observation across three production cycles revealed consistent procedural sequences: glutinous rice selection and washing, first steaming until half-cooked (90-100°C, 20-25 minutes), natural coloring with *katuk* leaf extract (*Sauropus androgynus*), second steaming until fully cooked (90-100°C, 25-30 minutes), cooling to inoculation temperature (30-35°C), *ragi* application (2-3% w/w) with thorough mixing to ensure uniform distribution, wrapping in rose apple leaves (*Syzygium aqueum*), and fermentation (48-72 hours, ambient temperature 25-30°C).

The scientific content encompasses multiple chemistry domains. Enzymatic starch hydrolysis represents the central process: amylase enzymes from Rhizopus oligosporus and Saccharomyces cerevisiae in ragi catalyze breakdown of starch polymers $(C_6H_{10}O_5)_n$ into glucose monomers ($C_6H_{12}O_6$), explaining the characteristic sweetness. Concurrent alcoholic fermentation converts glucose to ethanol (C_2H_5OH) and carbon dioxide via glycolytic pathways, producing the distinctive aroma and mild alcohol content (~3-6%). Temperature control proves critical: excessive heat denatures enzymes, while insufficient warmth slows microbial activity. Rose apple leaf wrapping serves dual functions—creating microaerobic conditions favoring specific fermentation pathways while contributing phenolic compounds with antimicrobial properties that prevent contamination. This single practice connects to curriculum topics including: organic chemistry (carbohydrate structure, functional groups), biochemistry (enzyme catalysis, metabolic pathways), solution chemistry (concentration, pH effects), and reaction kinetics (temperature dependence, activation energy).

Jamasan Keris: Redox Reactions and Corrosion Inhibition

Jamasan keris rituals involve systematic cleaning to remove iron oxide corrosion products while applying protective coatings. Observation of ceremonial and maintenance sessions revealed multi-stage procedures: initial washing with coconut water, scrubbing with lime juice, rinsing with floral water, thorough drying, and oil application.

The scientific content centers on electrochemistry and redox reactions. Rust formation represents oxidation of iron: $Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$, with oxygen reduction completing the redox couple: $O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$. The resulting iron oxides (Fe_2O_3, Fe_3O_4) appear as reddish-brown surface deposits. Lime juice (citric acid, $C_6H_8O_7$) functions as chelating agent, forming soluble iron-citrate complexes that facilitate rust removal while lowering local pH to enhance dissolution. Coconut water provides initial aqueous medium with mild acidity. Post-cleaning oil application (traditionally coconut or aromatic oils) creates hydrophobic barrier preventing water contact—the essential requirement for corrosion. Some practitioners add aromatic compounds (clove oil, patchouli) which contain antioxidants providing additional protection. Relevant curriculum connections include: electrochemistry (redox reactions, oxidation states), solution chemistry (acids, pH, solubility), organic chemistry (carboxylic acids, esters), and reaction energetics (spontaneous processes, corrosion thermodynamics).

Genteng Jatiwangi: Ceramic Materials and Thermochemistry

Traditional roof tile production involves thermal transformation of clay minerals into durable ceramic materials. Observation across six production batches documented: clay extraction and preparation, molding, multi-stage drying (7-10 days), kiln loading, firing (5-7 days with temperature progression 300→900→1100°C), and controlled cooling (3-4 days).

The scientific content encompasses inorganic chemistry and materials science. Raw clay consists primarily of kaolinite [$Al_2Si_2O_5(OH)_4$] with varying quartz (SiO_2) and iron oxide (Fe_2O_3) content affecting final color. Firing triggers sequential transformations: dehydration (100-200°C) removes absorbed water; dehydroxylation (450-600°C) eliminates structural hydroxyl groups, converting kaolinite to metakaolin ($Al_2Si_2O_7$); vitrification (900-1100°C) initiates partial melting creating glassy phase that bonds particles. Iron oxide content determines final color—higher Fe_2O_3 produces characteristic red-orange tiles. Temperature control represents critical expertise. Practitioners monitor smoke color, kiln glow, and timing to infer internal temperature without instruments. Premature cooling causes thermal stress cracking; insufficient peak temperature yields weak, porous tiles. Optimal firing produces compact, low-porosity ceramic with water absorption <15%. Curriculum connections include: inorganic chemistry (mineral structures, composition), thermochemistry (endothermic/exothermic processes, energy changes), reaction kinetics (temperature effects, phase transitions), and materials properties (density, porosity, strength).

Practitioners' Tacit Knowledge and Quality Indicators

Across all three contexts, practitioners demonstrated sophisticated embodied knowledge not fully captured in verbal explanations. Mr. A assessed fermentation readiness through simultaneous evaluation of multiple sensory parameters—sweet aroma intensity, soft-but-not-mushy texture, translucent appearance—that she described simply as "knowing when it's ready." This multi-parameter judgment corresponds to enzymatic activity curves: optimal sweetness indicates maximum glucose accumulation before excessive alcohol production. Mr. B distinguished between "dead rust" (loose surface oxides, easily removed) and "living rust" (adherent oxides requiring stronger treatment), adjusting citric acid concentration accordingly. His terminology reflects empirical understanding of oxide layer adhesion and chemical reactivity. Mr. C monitored firing through smoke color progression—thick white (moisture evaporation), gray (organic combustion), thin blue-white (peak temperature)—correlating visual cues with temperature zones. This tacit knowledge substitutes for pyrometric instruments through pattern recognition developed over

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decades. Temporal consistency across multiple observations validated these quality indicators as stable traditional knowledge rather than idiosyncratic practices.

Student Preconceptions and Misconceptions

To inform instructional design (MER Component 2), we administered multiple-choice instruments assessing student understanding of chemical processes underlying the three reconstructed local wisdom contexts: *jamasan keris*, *peuyeum ketan*, and *genteng* Majalengka. Ninety high school students (ages 16-17; Grade 12) from three schools in Ciayumajakuning completed the surveys (May 2024).

Instrument Quality and Rasch Analysis

Response data were analyzed using Rasch measurement model to assess instrument quality and identify misconception patterns. Rasch analysis provides robust evaluation of item difficulty, person ability, and instrument reliability through fit statistics (infit and outfit mean square values) and separation indices (Bambang Sumintono & Wahyu Widhiarso, 2014; Bond & Fox, 2013)

Results revealed varying instrument quality across the three contexts:

- *Jamasan Keris*: Good model fit (infit/outfit MNSQ ≈ 1.0); adequate item reliability (0.77); separation index 1.84 indicates acceptable ability to distinguish student understanding levels; low measurement error (RMSE = 0.51). This instrument demonstrated sufficient psychometric quality for detailed misconception analysis.
- *Peuyeum ketan*: Acceptable model fit (infit/outfit MNSQ ≈ 1.0) but low item reliability (0.43); separation index only 0.87 indicates poor discrimination among ability levels; higher measurement error (RMSE = 0.58). While model fit was satisfactory, the low reliability suggests items require revision—potentially expanding item pool or ensuring greater difficulty variation.
- *Genteng* Majalengka: Acceptable model fit (infit/outfit MNSQ within tolerance range) but very low item reliability (0.28); separation index 0.62; insufficient item difficulty variation to effectively distinguish student abilities. Instrument requires substantial revision for reliable measurement.

Based on reliability thresholds (>0.70 considered adequate), only the *jamasan keris* instrument achieved sufficient reliability for detailed misconception analysis. The low reliability in *peuyeum ketan* and *genteng* instruments likely stems from: (1) misfit items not adequately measuring intended constructs, (2) insufficient item difficulty variation—most items clustered at similar difficulty levels, and (3) possible unclear item wording or unfamiliarity with cultural contexts affecting response consistency (Azwar, 2022).

The low reliability, while limiting definitive misconception identification for peuyeum and *genteng* contexts, itself provides valuable diagnostic information: it suggests students lack coherent conceptual frameworks for these topics, resulting in inconsistent response patterns. This finding supports the need for culturally-grounded instruction that explicitly builds conceptual scaffolding.

Misconception Patterns: Jamasan Keris (Corrosion Inhibition and Redox Chemistry)

Detailed item analysis of *jamasan keris* responses revealed specific conceptual challenges. The instrument showed mean difficulty of 0.00 logits, indicating balanced distribution between easier (negative logit) and harder (positive logit) items. Most items demonstrated acceptable fit statistics and adequate point-measure correlations. Observed correct response percentages generally matched or exceeded model expectations, confirming overall good item quality. The most difficult item was Item 21 (difficulty measure = 2.73 logits— substantially above mean 0.00):

How does tannin inhibit metal corrosion?
a. Produces metal oxide
b. Forms protective iron-tannate layer [correct answer]
c. Reduces electron quantity
d. Prevents water contact
e. Increases oxidation

This item's exceptionally high difficulty indicates most students could not answer correctly. Analysis of response patterns and distractor effectiveness suggests several conceptual barriers:

1) Complex interdisciplinary concept: tannin-based corrosion inhibition requires integration of organic chemistry (phenolic compound structure, functional groups) and electrochemistry (redox reactions, passivation mechanisms). Students rarely encounter organic compounds as corrosion inhibitors in conventional chemistry instruction, which typically emphasizes metallic or inorganic protective coatings (zinc plating, paint barriers),
2) Unfamiliar chemical mechanism: formation of iron-tannate protective complex involves coordination chemistry and surface complexation reactions not typically covered in secondary chemistry curriculum. Students lack conceptual framework for how organic molecules chemically interact with metal surfaces beyond simple physical coating,
3) Effective distractors revealing alternative conceptions:
   - Option (a) "produces metal oxide" attracted students who recognize oxide formation in corrosion but misunderstand tannin's preventive rather than oxidative role. This reflects confusion between corrosion products (undesirable oxides) and protective oxide layers (passivation).
   - Option (d) "prevents water contact" appealed to students with mechanistic but non-chemical understanding—viewing tannin as physical barrier like oil coating rather than chemical complexing agent.
   - These distractors successfully discriminated between superficial understanding (corrosion involves oxygen/water) and deep mechanistic knowledge (specific chemical interactions prevent electron transfer).
4) Disconnect from tangible experience: Students failed to connect plant- derived tannins—familiar from tea, traditional medicine, astringent taste— with industrial/traditional metal preservation applications. This represents broader difficulty transferring everyday chemical experience to formal scientific contexts.

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The misconception pattern reveals students view corrosion prevention through limited conceptual lens: primarily mechanical barriers (coating prevents contact) or simple oxide formation, without understanding sophisticated chemical interactions like complexation, chelation, and passivation that underlie traditional preservation techniques documented in our ethnographic observations.

Preliminary Patterns: Peuyeum ketan and Genteng Majalengka

Despite low instrument reliability is precluding definitive misconception identification, preliminary analysis of *peuyeum ketan* and *genteng* Majalengka responses revealed suggestive patterns warranting further investigation with revised instruments.

In *peuyeum* context, student responses suggested prevalent confusion between fermentation and decomposition. Informal analysis of distractor selection indicated many students:

- Perceived fermentation as "rotting" or uncontrolled degradation rather than enzymatically-controlled transformation
- Could not explain sweetness origin, with responses attributing it to "added sugar" rather than enzymatic starch hydrolysis
- Anthropomorphized microbial processes (e.g., "yeast eats the rice") without understanding enzymatic catalysis at molecular level

These preliminary findings align with broader patterns in biochemistry education where students struggle to distinguish controlled biological processes from uncontrolled decomposition (Nix et al., 2022). The culturally-familiar context (*peuyeum* production) paradoxically exposed gaps: students' everyday observation of the process did not translate to scientific understanding of underlying mechanisms.

In *genteng* context, response patterns suggested students predominantly view ceramic firing as physical rather than chemical transformation:

- Conceptualizing firing as "simple hardening" analogous to "drying in oven"
- Believing heat "squeezes water out" rather than triggers chemical phase transitions
- Unable to explain color changes, attributing them to "paint" or "dye" rather than iron oxide chemistry

This pattern reflects common difficulty distinguishing physical (state changes, evaporation) from chemical transformations (bond breaking/forming, new substance formation)—a persistent alternative conception in chemistry education (Ahtee & Varjola, 1998; Schmidt & Volke, 2003).

Cross-Context Analysis and Pedagogical Implications

Despite varying instrument reliability, several cross-cutting patterns emerged with implications for culturally-grounded instruction:

1) Physical vs. Chemical Change Confusion: Across all three contexts, students consistently interpreted chemical transformations as physical processes—fermentation as rotting (physical decay), ceramic firing as drying (physical hardening), corrosion prevention as physical coating. This fundamental

misconception indicates students lack robust criteria for distinguishing physical and chemical changes beyond superficial markers (color change, gas production).

2) Difficulty Connecting Molecular and Macroscopic Levels: Students struggled to link observable phenomena in traditional practices (rust prevention, sweetness development, ceramic hardening) to underlying molecular mechanisms (redox reactions, enzymatic hydrolysis, mineral phase transitions). This reflects broader challenge in chemistry education: bridging macroscopic observation and submicroscopic explanation (Johnstone, 1993).
3) Limited Transfer from Abstract to Applied Contexts: Chemical concepts taught abstractly in formal curriculum (redox, enzymes, phase transitions) were not spontaneously applied to culturally-familiar contexts. This suggests compartmentalized knowledge: students learn concepts for exams but do not recognize their operation in everyday cultural practices. The cultural contexts, rather than facilitating understanding, revealed extent of compartmentalization.
4) Interdisciplinary Integration Challenges: Items requiring integration across chemistry subdisciplines (organic chemistry + electrochemistry for tannin; biochemistry + thermodynamics for fermentation) proved most difficult, indicating curriculum typically presents chemistry as isolated topics rather than interconnected system. Traditional practices naturally integrate multiple chemical principles, but students lack frameworks for such integration.

These findings support conceptual change research showing students hold persistent alternative frameworks resistant to traditional instruction (Duit & Treagust, 2003; Treagust & Won, 2023). The culturally-grounded contexts served dual function: they revealed misconceptions more clearly (students' familiarity with practices exposed gaps between observation and explanation) while simultaneously offering pedagogical opportunities. Practitioners' tacit quality indicators—documented through ethnographic observation—can become inquiry entry points for conceptual bridging.

Discussion

Pedagogical Implications: Bridging Cultural Knowledge and Scientific Understanding

The integration of ethnographic observation with Rasch-validated student preconception data reveals critical insights for culturally-grounded chemistry instruction. Our findings demonstrate that traditional practices embody sophisticated chemical knowledge—practitioners like Mr. B coordinate complex redox chemistry through empirical indicators developed across generations—yet students familiar with these cultural practices lack scientific frameworks to explain them. This paradox creates both challenges and opportunities for contextual learning.

The *jamasan keris* misconception data illustrate this tension. Item 21's exceptional difficulty (measure = 2.73 logits) revealed that most students could not explain tannin's corrosion-inhibiting mechanism, despite many having observed *keris* cleansing rituals in their communities. Students' attraction to distractors like "prevents water contact" (viewing tannin as mechanical barrier) or "produces metal

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oxide" (confusing corrosion products with protection) indicates they observe the practice's effectiveness without understanding its chemical basis. This finding challenges assumptions that cultural familiarity automatically facilitates scientific understanding—observation alone does not yield conceptual insight without explicit pedagogical bridging.

However, practitioners' tacit knowledge offers precisely such bridges. Mr. B distinguishes "dead rust" (loose oxides, easily removed) from "living rust" (adherent oxides requiring stronger treatment), adjusting citric acid concentration accordingly. This empirical discrimination corresponds to chemical reality—different iron oxide forms (Fe_2O_3 vs. Fe_3O_4) exhibit different adhesion and reactivity—but expressed through accessible sensory language. Effective instruction can leverage such practitioner expertise: "Why does Mr. B use stronger lime juice for some rust? What chemical difference exists between loose and adherent oxides?" transforms intuitive practice into conceptual investigation.

For *peuyeum ketan* and *genteng* contexts where low instrument reliability precluded definitive misconception identification, the measurement challenges themselves provide diagnostic value. Students' inconsistent response patterns—reflected in low separation indices and high measurement error—suggest absence of coherent conceptual frameworks for fermentation and ceramic chemistry. This fragmentation likely stems from curriculum presenting these topics abstractly without tangible referents. Mr. A's multi-parameter fermentation assessment (sweet aroma, soft texture, and translucent appearance) observed consistently across three production cycles offers concrete quality indicators that students currently lack. Rather than abstract enzyme kinetics, instruction might begin: "How does Mr. A know fermentation is complete? What observable changes indicate optimal sweetness?" grounding molecular mechanisms in macroscopic phenomena.

The cross-context misconception patterns—particularly physical vs. chemical change confusion and difficulty connecting molecular/macroscopic levels—indicate students need explicit conceptual scaffolding that current curriculum does not provide. Traditional practices naturally integrate multiple chemical principles (*jamasan* combines organic chemistry, electrochemistry, solution chemistry), yet students compartmentalize these as separate topics. MER's systematic content structure analysis, informed by ethnographic documentation of actual practice, enables instructional designs that mirror this natural integration.

Methodological Contributions: Integrating Ethnography with Rasch Analysis

Our observation-centered ethnographic approach addresses methodological gaps in both ethnoscience education research and context-based chemistry instruction. Most ethnoscience studies employ survey or interview methods that cannot access tacit, embodied knowledge underlying traditional practices. For instance, Chibuye & Singh (2024) documented Zambian ethnochemistry through practitioner interviews, identifying traditional knowledge but not capturing practitioners' intuitive quality assessments, troubleshooting strategies, or sensory indicators that emerge only through extended observation. Similarly, Tawanda and

Mudau (2024) surveyed Zimbabwean indigenous knowledge without documenting actual practice—what practitioners say versus what they do.

Our eight-month engagement with temporal replication enabled documentation of subtle expertise invisible to brief observation: Mr. A's simultaneous multi-parameter fermentation assessment, Mr.C's smoke color progression monitoring, and Mr. B's adaptive rust treatment strategies. These embodied competencies represent "knowing-in-action" (Schön, 2017) that practitioners demonstrate but may not articulate—precisely the knowledge most valuable for grounding abstract chemistry in tangible experience.

Conversely, context-based chemistry education research—while methodologically rigorous—typically develops artificial or simplified contexts rather than authentic cultural practices. Demelash et al. (2023) implemented context-based instruction in Ethiopia using 7E learning cycle with simulations, demonstrating effectiveness (n=229, experimental design) but relying on researcher-created scenarios about industrial processes students rarely encounter. Assi and Cohen (2024) combined flipped classroom with context-based learning in Israel using everyday chemistry contexts (food, household products), but these lack the cultural embeddedness and intergenerational transmission that characterize traditional knowledge systems. Our approach preserves cultural authenticity while maintaining pedagogical systematicity.

The integration of Rasch analysis with ethnographic data represents methodological innovation. Rasch modeling provides rigorous psychometric evaluation of student understanding, identifying not just what students know but how consistently they apply knowledge across item difficulties. The low reliability for peuyeum and *genteng* instruments—while initially appearing problematic—actually revealed important diagnostic information: students' conceptual frameworks for these topics are insufficiently coherent to produce consistent response patterns. This finding would be invisible in traditional percentage-correct scoring. Moreover, Rasch item difficulty measures (logits) enable precise identification of conceptual thresholds: Item 21's difficulty (2.73 logits) quantifies exactly how challenging tannin-corrosion mechanism is relative to other electrochemistry concepts, informing targeted instructional intervention.

International Comparison and Geographic Diversification

Recent systematic reviews confirm ethnoscience integration as global trend. Latip et al. (2024) analyzed 52 articles (2014-2023) on local/indigenous knowledge integration, finding most studies identify cultural practices without systematic pedagogical reconstruction into learning materials. Our MER- ethnography integration provides replicable framework addressing this gap, demonstrating how content structure analysis (Component 1) combined with learners' perspective investigation (Component 2) yields actionable instructional insights.

Geographically, ethnoscience research concentrates in Africa (Nigeria, South Africa, Kenya, Zimbabwe, Zambia) and North America (indigenous education in Canada, USA). Recent African studies include Chibuye & Singh (2024) Zambian ethnochemistry documentation and Tawanda and Mudau (2024) investigation of

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indigenous knowledge and metacognition in Zimbabwe. Southeast Asian ethnoscience chemistry research remains limited despite rich traditional knowledge systems. Zidny and Eilks (2022) explored sustainability education through Indonesian indigenous knowledge, but deep ethnographic reconstruction for chemistry curriculum development is scarce. Our Indonesian focus contributes to geographic diversification while demonstrating transferable methodologies applicable across cultural contexts.

Implementation Challenges and Recommendations

Despite pedagogical potential, several implementation challenges emerged from this research. First, practitioner accessibility: declining numbers of expert practitioners and hesitancy to participate (concerns about cultural appropriation, commercialization of traditional knowledge) constrained recruitment. Building trust required extended community engagement and cultural authority mediation—resources not readily available to individual teachers. We recommend establishing regional ethnoscience databases documenting traditional practices with scientific analysis and pedagogical guidance, making resources accessible without requiring each educator to conduct independent fieldwork.

Second, time intensity: eight-month ethnographic engagement is feasible for research but impractical for routine curriculum development. However, our documented findings—detailed observation notes, practitioner interview transcripts, quality indicator descriptions—provide reusable resources for subsequent instructional material development. Creating open-access repositories of such ethnographic documentation would enable broader implementation.

Third, scientific accuracy verification: ensuring traditional practices are presented with chemical rigor requires disciplinary expertise. Practitioners' empirical knowledge is accurate within its domain but not automatically translatable into formal chemistry concepts without expert validation. Our multi-level triangulation (observation, practitioner explanation, literature, expert review) illustrates necessary validation processes. Teacher professional development programs should include training on ethnoscience pedagogy and scientific validation methods.

Fourth, assessment alignment: while Indonesia's *Kurikulum Merdeka* provides philosophical support for culturally-grounded learning ("mindful, meaningful, joyful"), assessment systems still emphasize decontextualized knowledge. The low reliability of our peuyeum and *genteng* instruments—requiring students to apply chemistry concepts to unfamiliar cultural contexts—highlights assessment design challenges. Developing and validating culture-based assessment instruments requires sustained effort, as evidenced by our need for instrument revision and re-piloting.

We recommend: (1) forming partnerships between schools and cultural practitioners facilitating authentic student engagement; (2) developing comprehensive teacher guides translating ethnographic findings into lesson plans, with explicit attention to student misconceptions; (3) creating culture-based assessment instruments aligned with ethnoscience learning objectives; and (4) establishing communities of practice where educators share ethnoscience teaching experiences and resources.

Study Limitations

Several limitations qualify our findings. First, single practitioners per context—while mitigated through extended engagement (8 months, 15 cycles) and systematic triangulation—limit our ability to distinguish individual variation from broader traditional patterns. Second, geographic specificity: practices in Ciayumajakuning may differ from other Indonesian regions; generalization requires comparative studies. Third, this study completed MER Components 1-2 (content analysis, learners' perspectives) but not Component 3 (instructional design evaluation)— actual teaching effectiveness remains untested.

Future research should: (1) expand to multiple practitioners per context documenting variation and establishing core vs. peripheral traditional knowledge elements; (2) conduct comparative ethnographic studies across Indonesian regions investigating how geography, ethnicity, and modernization influence traditional practices; (3) revise and validate preconception instruments, particularly for *peuyeum ketan* and *genteng* contexts; (4) design, implement, and rigorously evaluate instructional interventions based on these findings, measuring impacts on conceptual understanding, scientific literacy, and cultural identity; and (5) investigate long-term retention and transfer effects of culturally-grounded chemistry learning.

4. Conclusion

This ethnographic study successfully addressed three research questions regarding scientific reconstruction of local wisdom for contextual chemistry education in Ciayumajakuning. First, eight-month participatory observation documented practitioners' sophisticated tacit knowledge underlying traditional practices. Master practitioners demonstrated embodied expertise—multi-parameter fermentation assessment, adaptive rust treatment distinguishing "dead" versus "living" oxides, smoke color temperature monitoring—that aligns with formal chemical principles (enzymatic kinetics, redox reactions, thermochemical transformations) but expressed through accessible sensory language. These quality indicators offer pedagogical bridges from observable phenomena to molecular mechanisms. Second, Rasch analysis revealed significant student misconceptions despite cultural familiarity. Cross-context patterns revealed persistent confusion between physical and chemical change, inability to connect molecular and macroscopic levels, and compartmentalized knowledge resistant to application in cultural contexts. Third, integrating ethnographic and psychometric data enables targeted instruction: practitioners' indicators become inquiry starting points, misconception patterns inform explicit scaffolding. This methodological

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integration—observation-centered ethnography capturing tacit knowledge combined with rigorous Rasch assessment— addresses gaps in both ethnoscience research (brief surveys) and context-based instruction (artificial scenarios). Key contributions include methodological innovation, empirical documentation of endangered traditional knowledge, pedagogical pathways for culturally-grounded learning, and geographic diversification. However, limitations remain: single practitioners limit generalizability, instruments require revision, and MER Component 3 (instructional evaluation) remains incomplete. Future research must design and rigorously evaluate teaching interventions measuring actual impacts on student understanding, scientific literacy, and cultural identity. These findings provide validated foundation for developing materials that honor cultural heritage while advancing chemistry education.

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