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Ethnochemistry: Potential, Implementation, and Challenges of Integrating Local Wisdom to Enhance Student Motivation and Engagement

Faathir Almur* & Hastuti Agussalim
Chemistry Department, Faculty of Mathematics and Natural Sciences, Universitas Negeri Makassar, Jl. A.P. Pettarani, Makassar, Indonesia
*Corresponding Author e-mail: faathir.almur@unm.ac.id

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Abstract
Chemistry is often perceived as an abstract and challenging subject, leading to low student motivation and engagement. This article aims to investigate the role of ethnochemistry, integration of local wisdom into chemistry instruction as an innovative approach to address this issue. A thematic literatur review was conducted by analyzing 10 articles from indexed national and international journals (Google Scholar, Scopus, SINTA) published between 2015 and 2025. The findings reveal that ethnochemistry has been implemented through diverse cultural contexts, such as batik-making, traditional food fermentation, and the use of medicinal plants, which are linked to core chemistry concepts (e.g., redox reactions and chemical bonding). Its implementation is most effective when combined with active learning models such as Project-Based Learning (PjBL) and Contextual Teaching and Learning (CTL). This review contributes by identifying the effective configuration of ethnochemistry within active learning, highlighting its holistic impact on motivation, multidimensional engagement, and cultural-scientific literacy, while critically mapping key implementation challenges. Key findings indicate that this approach significantly enhances learning motivation, cognitive achievement, knowledge retention, and student engagement across behavioral, emotional, and cognitive dimensions. Furthermore, ethnochemistry strengthens students' cultural identity and scientific literacy. However, its implementation faces challenges, including limited standardized teaching materials, the need for teacher capacity building through specific training, and selectivity due to not all chemistry topics being contextually compatible with local wisdom. It is concluded that ethnochemistry is a promising approach to make chemistry learning more relevant and engaging, effectively boosting student motivation and participation in learning activities.

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INTRODUCTION

Chemistry holds a pivotal role as a science that bridges physics, biology, and applied fields such as engineering, medicine, and environmental science (Reyes, 2025). It is essential for understanding natural phenomena and global challenges, making its instruction a priority at the senior high school level. However, chemistry is often perceived as a difficult subject by students. A study by Muderawan (2019) found that the majority of students (83%) in a particular school experienced high to very high levels of difficulty in learning certain chemistry topics, such as solubility. One of the main reasons students struggle with chemistry is their inability to see its relevance to daily life, leading to low engagement in the learning process (Demelash, 2024). This issue is exacerbated by conventional teaching methods that are often expository (lecture-based), rendering students passive in the classroom and diminishing their learning motivation.

Various studies indicate low motivation and engagement among students in chemistry learning. For instance, Malaihollo et al. (2023) reported that the dominant use of direct instruction models results in student passivity and reduced learning motivation. Demelash et al. (2024) also emphasized that the level of engagement among middle school students in chemistry remains relatively low. In Indonesia, Saputri et al. (2025) found that the average score for chemistry learning motivation among high school students was only around 3.45 (on a 1–5 scale), indicating suboptimal motivation. These findings are consistent with the fact that many students perceive chemistry as having abstract content. Consequently, students' learning outcomes in chemistry tend to stagnate, accompanied by low interest in the subject.

The complex nature of chemistry demands a different pedagogical approach from teachers (Kausar, 2024). To address these challenges, a contextual and culturally relevant teaching approach is needed. One emerging approach is ethnochemistry based on local wisdom. According to Munandar et al. (2024), ethnochemistry connects chemical concepts with local community practices and wisdom, thereby providing more meaningful contextualization of the material for students. By utilizing local cultural knowledge, such as food traditions, craft making, or natural resource processing, chemistry learning becomes more relevant to students' lives. Integrating ethnochemistry into chemistry education can enhance conceptual understanding, scientific skills, creativity, and student engagement in the learning process. This approach also helps preserve traditional chemical knowledge that is at risk of being lost, ensuring that learning is not only scientific but also culturally nuanced.

Another advantage of ethnochemistry is its ability to intrinsically motivate students. Aldiansyah et al. (2023) assert that ethnochemistry has proven effective in increasing chemistry learning motivation and students' interest in the subject. Learning experiences built upon local wisdom make chemistry feel closer and more meaningful to students' cultural identities. Thus, ethnochemistry not only enriches the learning context but also stimulates curiosity and enthusiasm among students. Various studies conclude that this approach makes the chemistry learning process more relevant and promotes active student engagement.

However, previous studies on ethnochemistry tend to be fragmented, for example focusing only on the application of a particular learning model or specific local wisdom as teaching materials, without providing a comprehensive synthesis of the most effective implementation configuration to enhance student motivation and engagement. Furthermore, many studies emphasize potential and positive outocme without in-depth analysis of the operational challenges and conceptual limitations in integrating it into the formal curriculum. Therefore, this study needed that can comprehensively syntehsize these various findings to provide of how ethnochemistry can be optimally implemented to enhance student motivation and engagement. To address this gap, this article employs a thematic literature review to comprehensively analyze and integrate findings from diverse empirical studies. This method enables a structured, replicable, and thematic synthesis that identifies effective pedagogical configuration while also uncovering cross contextual implementation challenges.

METHOD

Research Design

This article employs a thematic literature review design to analyze and synthesize findings from various literature sources related to the topic of ethnochemistry. The aim of this approach is to build a comprehensive understanding of recent developments in the field of chemistry education. Thematic synthesis was selected because it allows for comparison across qualitative findings while maintaining a transparent link between the conclusions drawn and the original data reported in primary studies. According to Thomas and Harden (2008), thematic synthesis is a well-established and rigorous method that preserves contextual meaning and ensures transparency, which are core principles of systematic reviewing.

To ensure comprehensive coverage, literature search was conducted across several databases using predetermined keyword combinations. The analyzed articles were sourced from national and international journals indexed in Google Scholar, Scopus, and SINTA, with the publication timeframe limited to the last ten years (2015–

2025). From the initial search results, articles were systematically screened for relevance, leading to the final selection of literature that forms the foundation of this thematic review.

Inclusion and Exclusion Criteria

Article selection followed specific inclusion and exclusion criteria. The inclusion criteria were: (1) articles focusing on or combining topics related to the application of ethnochemistry or local wisdom-based learning, chemistry learning motivation, and student engagement in chemistry learning; (2) research subjects consisting of high school or equivalent level students; (3) articles containing empirical data. The exclusion criteria were: (1) articles not focused on chemistry learning; (2) articles discussing only elementary school or higher education levels; (3) non-journal reports such as proceedings, theses, or books (Sari, 2025).

Article Selection Procedure

The literature selection process was carried out in several stages: screening titles and abstracts to assess topic relevance, a full-text review of the articles, and thematic classification where articles were grouped according to themes. From this selection process, a number of articles deemed suitable for further analysis were obtained (Miterianifa, 2024).

Data Analysis Technique

Data analysis was conducted using the thematic analysis method, which is employed to identify, analyze, and report patterns within data. The steps taken in analyzing the data included initial coding of important sections of the articles. This was followed by identifying main themes, such as factors causing low learning motivation or the application of ethnochemistry. The subsequent stage involved synthesizing the findings to build connections between concepts for example, how cultural context in learning can enhance relevance and motivation and then constructing a comprehensive narrative that links all previous research findings. This approach is designed to yield an output that is primarily thematic, while also laying a foundation for theoretical and methodological contributions to the field of chemistry education (Yam, 2024). Through this process, the author not only seeks to offer an integrated and in-depth perspective on how the integration of local wisdom through an ethnochemistry approach can serve as an innovative solution to chemistry learning challenges.

RESULTS AND DISCUSSION

Result

The thematic analysis of the selected literature revealed several key patterns regarding the implementation of ethnochemistry. To provide a comprehensive overview, the main characteristics of the ten core studies are summarized in Table 1 below. This table serves as the empirical foundation for a more in-depth discussion on the role of local wisdom as a learning resource, the effectiveness of implementation models, and its impact on student motivation and engagement.

Table 1. Summary of Reviewed Ethnochemistry Studies Characteristics

No.	Article Title	Local Wisdom	Integration Model/Strategy	Findings
1	Green Chemistry and Cultural Wisdom: A Pathway to Improving Scientific Literacy among High School Students	The Use of Natural Dyes in Batik Making and the Role of Chemical Bonds	Integrated textbook of green chemistry and local wisdom of Indonesia	The integration of Green Chemistry and Local Wisdom in chemistry learning can improve students' science literacy and create a more inclusive and culture-based education
2	Effect of Ethnochemistry Approach on Academic Achievement and Retention of Chemistry Students in Separation Techniques in Egor Lova Government Area, Edo State	Local context of the mixture separation process	Comparing ethnochemical approaches with conventional lecture methods	Students who were taught with an ethnochemical approach had much higher cognitive achievement and retention than controls. Studies recommend incorporating ethnochemistry into chemistry curriculum to make learning more effective and relevant

No.	Article Title	Local Wisdom	Integration Model/Strategy	Findings
3	Etnochemistry in the Chemistry Curriculum in Higher Education: Exploring Chemistry Learning Resources in Sasak Local Wisdom	Merarik Tradition (Sasak Tribal Wedding)	Exploration of chemical concepts through the Merarik tradition	The social and moral values of the Merarik tradition are closely related to the concept of chemical bonds (electron stability, electron configuration, positive/negative ions). So that the Merarik tradition can be used as a learning resource to explain the theory of Chemical Bonds
4	Ethnochemistry: Exploring the Potential of Sasak and Jawa Local Wisdom as a Teaching Materials	Local Wisdom of Sasak and Java	Development of teaching materials that integrate local wisdom	The local wisdom of Sasak and Java was successfully integrated into the material of chemical bonding and material change. The author concludes that these cultural values can be used as a source of contextual chemistry learning
5	Chemistry Learning Strategies Based on Local Wisdom to Enhance Cultural Awareness and Understanding of Scientific Concepts	Various sources of local wisdom such as traditional medicine from natural ingredients	Literature review	The integration of local wisdom in chemistry learning strategies fosters the cultural identity and pride of students, especially students from the area, so that chemistry materials become more meaningful
6	The Effect of Implementing an Ethnochemistry Book Integrated with AR on Students Learning Motivation	Local examples such as pletok beer (Betawi), naniura (Manado), Dekke (Gorontalo)	Augmented reality integrated chemistry textbook	The experimental group (ethnochemistry AR book) had much higher learning motivation scores across all dimensions (e.g. interest, engagement, self-confidence) than the control
7	Integration of Local Knowledge in the Secondary School Chemistry Curriculum – A few examples of Ethno-Chemistry from Zambia	Ethnochemical practices such as knowledge of medicinal plants and local ingredients	Ethnographic studies	Many Zambian ethnochemical practices were found relevant to the study of chemistry; The use of local practices can enrich the teaching of chemistry for ethnically diverse students and increase students' interest and familiarity with chemistry
8	A Thematic Review: Ethnochemistry in Secondary Schools	Various examples of local wisdom in chemistry	Systematic literature review of 29 ethnochemical articles	Ethnochemistry-based chemistry lessons generally have a positive impact on the learning process and become a rich source of learning (contextual learning)
9	The Effectivenes of the Ethnochemistry-based Problem Based Learning Model on Students Problem Solving Ability in Chemistry Learning: A Meta Analysis Study in 2021-2024	Various examples of local wisdom in chemistry	Meta-analysis	The integration of ethnochemical aspects in chemistry learning increases the social and cultural relevance of the material studied and makes students more engaged and motivated

No.	Article Title	Local Wisdom	Integration Model/Strategy	Findings
				to actively participate in learning
10	Fostering Collaboration and Enhancing Student Learning Achievement through the Integration of Ethnoscience in the Common Knowledge Construction Model with Podcast Media	The relationship of ethnoscience to chemical bonding materials	Model Common Knowledge Construcion dan media podcast	The CKCM ethnoscience model significantly improves student learning outcomes on chemical bonding materials

Discussion

Diversity of Local Wisdom as a Contextual Resource for Chemistry Learning

A synthesis of the literature reveals that the implementation of ethnochemistry is rooted in diverse cultural practices that function as authentic and meaningful learning contexts. Researchers (Purba et al., 2025; Wahyudiati et al., 2022; Sutrisno et al., 2020; Chibuye & Singh, 2024) have documented how processes such as the fermentation of traditional foods (*tape*, *mandai*) and natural dyeing techniques for batik are not merely objects of study but can be successfully deconstructed into concrete expressions of fundamental chemical concepts like redox reactions, acid-base properties, and separation principles. This pattern indicates that local wisdom is not merely an illustration but constitutes its own system of knowledge containing a profound scientific logic. The successful connection established between tangible practices (for example, the processing of *bir pletok* or the forging technique of *keris* daggers) and formal chemical theory proves the existence of a cognitive bridge that can link everyday knowledge with scientific knowledge.

These findings reinforce and concretize the core principle of constructivist learning theory (Taber, 2024), which emphasizes that new knowledge is optimally constructed when integrated with students' prior experiences and cognitive schemas. Ethnochemistry operates by leveraging students' socio-cultural context as scaffolding to comprehend scientific abstractions. For instance, the concept of chemical bonding becomes more comprehensible when explained through the metaphors and values of cohesion in the *Merarik* (Sasak) traditional ritual, while the principle of reaction rates finds its relevance in the familiar process of fermentation. Thus, this approach effectively reduces the psychological distance between students and the subject matter, transforming chemistry from something foreign and abstract into something relevant, contextual, and meaningful. This process not only enhances conceptual understanding but also empowers students as active agents in constructing their own knowledge through interaction with their cultural heritage.

Implementation of Ethnochemistry

Effective implementation of ethnochemistry is realized through active pedagogical approaches that transform cultural contexts into authentic learning experiences. Project-Based Learning (PjBL) stands out as a popular model, where students not only learn but directly construct knowledge through the full cycle of a culture-based project, such as creating natural dyes or investigating fermentation, from orientation and investigation to presentation of results. The PjBL model provides a structural framework in the form of stages (inquiry, design, execution, presentation) oriented toward a product or prototype. This contributes to transforming cultural contexts into authentic activities and fostering 21st-century skills (Abu et al., 2025). The PjBL model also contributes to activating meaningful knowledge construction, which aligns with constructivist theory stating that knowledge is actively built by learners, not passively received (Mones et al., 2023). Passive approaches such as the lecture method in ethnochemistry risk reducing culture to mere illustration.

Learning models that require student activeness need to be reinforced by strategies such as Contextual Teaching and Learning (CTL), which raises local issues as a starting point for inquiry, as well as the development of teaching materials based on Culturally Responsive

Teaching enriched with technology (augmented reality, podcasts). Technology serves as an enhancer that enriches and facilitates the process. For example, augmented reality can visualize molecular structures in cultural processes, podcasts can bring cultural expert narratives into the classroom, and digital platforms can facilitate project collaboration and documentation.

CTL acts as scaffolding that ensures every project phase remains connected to the local context and meaningful for students (Ester et al., 2023). Therefore, ethnochemistry is optimal when there is a strong and authentic conceptual bridge between chemistry concepts and cultural practices, for example, acid-base concepts in vinegar, colloids in making coconut milk, and electrochemistry in metal preservation techniques. Learning will be more optimal if the chosen cultural context is close to daily life or the cultural background of the majority of students. Ethnochemistry learning with the CTL strategy will be less optimal if the topics raised are highly abstract and microscopic, such as electron configuration and orbital quantum mechanics.

Consistent findings from various studies confirm that the integration of ethnochemistry within such an active pedagogical framework significantly enhances students' intrinsic motivation and holistic engagement. This mechanism works because such approaches directly operationalize constructivist principles on a personal and contextual level. This aligns with research findings stating that engagement in meaningful, relevant activities that provide autonomy can increase intrinsic motivation (Reeve & Cheon, 2021).

Meaningful cultural contexts function as emotional and cognitive bridges, providing a relevance framework that makes students feel connected (emotional engagement), while also presenting investigative challenges that encourage active exploration (cognitive and behavioral engagement). For example, a study by Anor et al. (2022) on cassava dough preparation showed that familiar cultural contexts facilitate simultaneous engagement in all three dimensions. Thus, the local context in PjBL or CTL is not merely a frame but a driver that transforms learning into a process of self-discovery where students feel ownership and authority over their own knowledge, as evidenced by a significant increase in motivation (Purba, 2025).

Implication of Ethnochemistry in Learning

Empirical evidence consistently affirms the positive impact of integrating ethnochemistry, particularly in enhancing student motivation and engagement. Quantitative findings, such as those reported by Purba et al. (2025) and Oyeyemi (2024), show significant changes in learning motivation, cognitive achievement, and memory retention in the experimental groups. However, these results represent only the surface of a deeper transformation. The main implication lies in the ability of this approach to align the mastery of scientific literacy with the strengthening of cultural identity, while simultaneously activating psychological and pedagogical mechanisms that encourage active student participation.

Ethnochemistry increases motivation by building personal and contextual relevance. Subject matter linked to culture, traditions, or local practices makes abstract science concrete and relevant to students' daily lives. This reduces the psychological distance between students and the material, making it easier for them to see the benefits and meaning of what they are learning. This connection triggers intrinsic motivation to learn and increases students' self-confidence (Willenda et al., 2024).

Effective learning occurs when new knowledge is built upon prior knowledge. Local wisdom serves as the foundational knowledge that students already possess. For example, understanding the concept of *tape* (fermented cassava) fermentation can facilitate comprehension because students already have experience related to the process. This ease reduces anxiety and increases students' belief in their ability to master the material. This aligns with the findings of Diana et al. (2025), which state that learning with a Culturally Responsive Teaching approach increases learning motivation in terms of the needs for self-actualization and safety.

Chemistry learning linked to culture often involves real-world problems or practices. This prompts students to ask questions, propose hypotheses, and collaboratively seek answers. Several cultural practices, such as fermentation in making *tape*, can be used as practical activities that require students to be physically and cognitively active. Students are required to interact with materials, discuss with peers, and solve problems together. This process transforms the student's role from a passive information receiver to an active agent in knowledge construction, thereby enhancing student learning activity (Arista et al., 2024). Thus, ethnochemistry not only makes students want to learn but also gets them actively involved in the learning process.

Ethnochemistry realizes the principles of Culturally Responsive Teaching by empowering students through their cultural identity. Several studies indicate that students can appreciate their cultural heritage while understanding the scientific concepts behind such practices (Irpan et al., 2024). Consistent with this, approaches that integrate local values have proven to provide contextual and meaningful learning experiences, while also strengthening conceptual understanding, preserving culture, and increasing active student engagement (Putra & Wahyuni, 2025).

The process is the core realization of Culturally Responsive Teaching, which aims to empower students by making their cultural backgrounds a legitimate epistemological starting point. By valuing local wisdom as a valid source of knowledge, ethnochemistry implicitly trains students in critical and contextual scientific literacy, the ability to analyze, connect, and apply concepts within their socio-cultural reality. Ultimately, such learning not only transfers chemical knowledge but also fosters a scientific awareness rooted in culture, shaping individuals who not only understand science but also value their identity and cultural sustainability.

Challenges and Critical Reflections on the Implementation of Ethnochemistry

Despite its numerous benefits, the implementation of ethnochemistry is not without various challenges. Key obstacles include the limited availability of standardized, scientifically-validated teaching materials, which often requires teachers to independently develop their own resources. Fundamentally, this approach also has substantive limitations, as not all chemistry topics can be effectively taught through local wisdom. As highlighted by Azizah (2021), the application of ethnochemistry can only be integrated into specific topics that exhibit conceptual alignment with cultural potential and must align with core and basic competencies. This necessitates educators to critically identify and select relevant local cultural potentials corresponding to the learning material.

Teacher capacity emerges as a crucial concern, where adequate training is required to accurately link cultural practices with chemical concepts. This aligns with concerns among pre-service chemistry teachers regarding limited experience and a lack of specific pedagogical training in the ethnoscience approach. More specifically, they also encounter difficulties in selecting and identifying cultural examples that precisely match certain chemical concepts (Hayon, 2025). Other practical challenges include constraints on time and facilities, particularly for learning models involving fieldwork or laboratory use. Therefore, implementation efforts require strong systemic support, encompassing ongoing training, material development, and strategic partnerships.

Although the evidence presented shows consistent positive impacts of the ethnochemistry approach, it must be acknowledged that most of the studies reviewed tend to come from educational contexts with specific and homogeneous cultural characteristics. Therefore, generalizing the findings to more diverse educational settings may not yield optimal results. On the other hand, while improvements in student motivation and engagement are reported as significant, these claims should be interpreted cautiously given variations in research design, measurement tools, and differing implementation durations across studies. Consequently, although ethnochemistry offers a promising pathway for more contextual chemistry learning, its overall effectiveness still requires verification through more rigorous comparative research and implementation approaches that are sensitive to cultural diversity and teacher pedagogical readiness.

CONCLUSION

Based on the findings of the study, the integration of local wisdom and cultural practices into chemistry education has significant potential to enhance material relevance, intrinsic motivation, and student participation through cultural contextualization, which makes learning more relevant and meaningful. Project-based learning and contextual learning models supported by ethnochemistry modules and digital media are most frequently associated with positive outcomes. The main implication of this study is to provide an empirical basis and conceptual framework for educators and curriculum developers to design more inclusive and contextual chemistry learning. However, the success of implementation depends on the readiness of teaching materials, teacher capacity, facility support, and collaboration with local communities. More methodologically rigorous research and the development of standardized teaching materials are essential to scale up this practice.

RECOMMENDATION

This study yields practical recommendations for various educational stakeholders. For chemistry teachers, it is advised to explore and integrate local wisdom from their surrounding environment into instruction through active and contextual learning models. Furthermore, curriculum developers are encouraged to design chemistry curricula that incorporate space for localized content, such as through locally-relevant subjects or project-based enrichment modules. Meanwhile, for researchers, further investigation is needed to explore the long-term impact of ethnochemistry, the comparative effectiveness of different integration models, and the development and validation of standardized ethnochemistry teaching materials.

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