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# Ethnochemistry Supports 21st Century Skills: Systematic Literature Review

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**Abstract**

This research aims to identify and analyze the contribution of ethnochemistry in supporting the development of 21st-century skills within the context of chemistry education. This study is important because many studies identify ethnochemistry as a highly potential field, but few have thoroughly examined how ethnochemistry can be applied to support the development of 21st-century skills. Using a Systematic Literature Review (SLR) approach, this research collects and evaluates relevant literature on the relationship between ethnochemistry and 21st-century skills. Thirteen articles were selected from a pool of 79 collected articles. Several 21st-century skills supported by the articles include scientific literacy, chemical literacy, critical thinking skills, and problem-solving abilities. The analysis shows that the dominant 21st-century skills supported are scientific literacy (46%) and chemical literacy (38%). These percentages are obtained by comparing the number of articles for each skill with the total number of articles analyzed. The conclusion of this study is that the 21st-century skills supported by ethnochemistry include scientific literacy, chemical literacy, critical thinking skills, and problem-solving abilities. However, there are still limitations: firstly, most studies are local and contextual; secondly, most studies use short-term designs, without long-term follow-up; thirdly, research instruments in several studies are limited to questionnaires and student perceptions, without data triangulation. This study recommends further research into the integration of ethnochemistry to support 21st-century skills such as critical thinking, problem-solving, creativity, collaboration, and others. Moreover, it is necessary to integrate ethnochemistry into the chemistry education curriculum, incorporating ethnochemistry as part of the teaching method that can enrich the teaching material with local cultural contexts.

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## INTRODUCTION

The rapid changes in various aspects of life in the 21st century have brought new demands in the field of education, especially related to the development of skills that are relevant to the needs of a globally connected and increasingly evolving industry. 21st-century skills such as critical thinking, creativity, collaboration, effective communication, digital literacy, scientific literacy, chemical literacy, problem-solving, and social and emotional skills are crucial for individuals to adapt and succeed in the dynamic and interconnected global era (Stanikzai, 2023) and (van Laar et al., 2020). Therefore, an educational approach is needed that not only emphasizes cognitive mastery but also connects scientific knowledge with the social and cultural contexts of students. Such an approach is reflected in the concept of ethnochemistry, which holds great potential in supporting the development of 21st-century skills through the integration of chemistry and local wisdom.

Ethnochemistry is a concept rooted in culture, which can make chemistry learning more enjoyable and relevant to students' daily lives (H. Sutrisno et al., 2020). This field offers an

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interesting perspective for linking chemical knowledge with practices and traditions that exist in various cultures worldwide. Integrating local cultural practices into chemistry education through ethnochemistry can increase student engagement and contextualize learning (Ardyansyah, 2024). Ethnochemistry not only includes the scientific aspects of chemical substances but also studies chemistry in conjunction with cultural anthropology through the study of specific community groups (Jofrishal* & Seprianto, 2020).

Ethnochemistry plays a role in preserving Indonesia's culture while fostering nationalism among students by encouraging reflection on identity and the introduction of local traditions and cultural values through the lens of chemistry. This promotes awareness, pride, and a sense of responsibility toward cultural heritage in the face of globalization (Rahmawati et al., 2023; Khasanah, 2019). The integration of ethnochemistry into chemistry lessons provides a richer and more meaningful learning experience because it is directly connected to everyday practices, not just theory and laboratory work. This connection enhances student interest and understanding of chemical concepts and their applications in local contexts (Wahyudiati, 2022; Pebrianti et al., 2024). In chemistry classes, the application of ethnochemistry can be carried out through various activities, such as experiments based on local natural materials, chemical analysis of traditional products, or studies of chemical processes in cultural practices, such as food fermentation, the production of natural dyes, and the preservation of traditional foodstuffs (Sutrisno et al., 2020;Yuliani et al., 2021).

Ethnochemistry has great potential, but its application in formal education, particularly its integration into the chemistry curriculum, remains limited (Sutrisno, 2020). Many studies have identified ethnochemistry as a highly promising field, but few have thoroughly examined how ethnochemistry can be applied to support the development of 21st-century skills. Therefore, it is essential to conduct research that further explores the connection between ethnochemistry and 21st-century skills in the context of education.

This research is significant because it connects two fields that are often considered separate: natural sciences and local wisdom. By exploring the contributions of ethnochemistry in education and the development of 21st-century skills, this study aims to identify and analyze the contribution of ethnochemistry in supporting the development of 21st-century skills in education. Using a Systematic Literature Review (SLR) approach, this study collects and evaluates relevant literature on the relationship between ethnochemistry and 21st-century skills, as well as how the application of ethnochemistry in the education curriculum can enhance students' skills, both in science and their social lives. This study is expected to provide a deeper understanding of ethnochemistry as an interdisciplinary approach that can enrich the chemistry learning process and support the development of the skills needed in the 21st century.

## METHOD

This study uses a Systematic Literature Review (SLR) design to identify trends in ethnochemistry-based learning that support 21st-century skills. The SLR approach, utilizing the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), is employed to identify, analyze, and synthesize various studies related to the application of ethnochemistry in chemistry education. The PRISMA approach was selected because it provides a systematic and transparent framework for the literature review process, ensuring that the results obtained are more valid and replicable (Page et al., 2021).

### Identification

The literature search was conducted across several scientific databases, including Google Scholar and Scopus, for publications from 2020 to 2025. The keywords used were

"ethnochemistry in chemistry education." Initial searches yielded 79 articles relevant to the research topic.

### Screening

The databases used included both national and international journals such as Scopus and SINTA. The selected articles were published within the last five years (2020–2025) and relevant to the research topic, totaling 79 articles. The articles were reviewed through reading the titles, abstracts, and content. After the screening process, 27 articles remained for further analysis.

### Eligibility

Full-text reading was then conducted to assess the suitability of the content with the focus of the study. Articles that did not address the integration of ethnochemistry in chemistry education were excluded from the analysis. After this phase, 13 articles met the eligibility criteria.

### Inclusion

A total of 13 final articles were analyzed using content analysis techniques to identify: (1) the role of ethnochemistry in supporting 21st-century skills, (2) the impact of ethnochemistry implementation on 21st-century skills, and (3) the challenges and opportunities of implementing ethnochemistry in various educational contexts. The results of the analysis were visualized in a PRISMA flow diagram (Figure 1), which illustrates the article selection process from the identification phase to final inclusion.


Figure 1. Prisma Flow Diagram: Ethnochemistry Supporting 21st Century Skills

## RESULTS AND DISCUSSION

This research began by searching and selecting articles from national and international journals through specific databases. The article search was conducted using keywords relevant to the research topic. Initially, 79 articles with similar themes were found, but after selection, only 13 were deemed most relevant to the research needs. The selected articles focused on in-depth discussions of ethnochemistry supporting 21st-century skills and the details shown in table 1.

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Table 1. 21st century skills integration from journal

| No | 21st century skills integration | Author | Article Titles | Journal | Findings | Limitation |
|---|---|---|---|---|---|---|
| **1.** | Ethnochemistry-oriented modules are effective in improving abilitie sscience literacy student | (Asda et al., 2023) | Development of Buffer Solution Students' Worksheet Based on Problem Based Learning with Ethnochemistry to Improve Students' Science Literacy Ability | Jurnal Penelitian Pendidikan IPA (S2) | Integration of local cultural contexts improved conceptual mastery and science literacy scores significantly. | Limited to buffer solution topic and short implementation period; lacks longitudinal evaluation. |
| **2.** | Chemical literacy students through learning using an ethnochemical approach | (Harianto et al., 2025) | Analysis of Students Chemical Literacy through Ethnochemistry Learning in Material Colligative Properties of Solution | IJIS Edu: Indonesian Journal of Integrated Science Education (S2) | Students related local salt-production practices with colligative properties, improving interpretation of abstract concepts. | Small sample size; no control for teacher or regional variables. |
| **3.** | The use of ethnochemical-based e-modules can improvechemical literacy student | (Dewi et al., 2024) | Ethnochemistry-Based E-Module: Does it Effect on Improving Students' Chemical Literacy | Journal of Innovation in Educational and Cultural Research (S1) | The ethnochemistry-based e-module improved students' chemical literacy and cultural appreciation. | Relies on self-reported questionnaire; lacks experimental control group. |
| **4.** | The effectiveness of using Adobe Flash based on ethnochemistry on science literacy student | (Heliawati et al., 2022) | Ethnochemistry-Based Adobe Flash Learning Media using Indigenous Knowledge to Improve Students' Scientific Literacy | Jurnal Pendidikan IPA Indonesia (S1) | Students' motivation and reasoning increased through contextual and visual learning media integrating indigenous knowledge. | Dependence on technology tools; limited offline applicability. |
| **5.** | The ethnochemistry textbook is considered very good and relevant as a learning medium for | (Hendrawani et al., 2025) | Development of An Inquiry-Based Ethnochemistry Textbook to Improve Students' Scientific Literacy and Understanding | Hydrogen Jurnal Kependidikan Kimia (S4) | Inquiry stages incorporating local culture improved conceptual understanding and literacy. | Limited classroom trials; lacks broader validation with other curricula. |

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| No | 21st century skills integration | Author | Article Titles | Journal | Findings | Limitation |
|---|---|---|---|---|---|---|
| | developingscience literacy | | | | | |
| **6.** | Implementing a learning strategy with Sasambo ethnochemistry to enhance chemical literacy | (Mutiah et al., 2024) | Implementation of Integrated Problem-Based Learning Model with Ethnochemistry Sasambo to Improve Chemistry Literation | Jurnal Pijar MIPA (S4) | Integration of Sasambo culture encouraged student engagement, reflection, and improved literacy. | Context limited to NTB region; generalization to other cultural contexts uncertain. |
| **7.** | Modules with ethnochemical content to improvescience literacy | (Pebrianti et al., 2024) | Development of the Acid-Base Module Based on Problem Based Learning with Ethnochemisty to Improve Students Science Literacy Ability | Jurnal Penelitian Pendidikan IPA (S2) | The module enhanced students' scientific reasoning and interest in local knowledge integration. | Sample restricted to one school and one concept area. |
| **8.** | The effectiveness of ethnochemical-based e-modules increases science literation | (Yanti et al., 2025) | Development of Technopreneurship-Based E-Modules for Ethnochemistry, Redox, and Science Literacy | APTISI Transactions on Technopreneurship (ATT) (S1) | The integration of culture and technopreneurship promoted creativity and literacy growth. | Lack of experimental control; no qualitative triangulation of student perceptions. |
| **9.** | The effectiveness of ethnochemicals in promoting chemical literacy among Indonesian high school students. | (Ridwan et al., 2025) | Bridging culture and chemistry: Implementing Ethnochemistry to Enhance Chemical Literacy of Indonesian High School Students | Multidisciplinary Science Journal (Q4) | Mini-ethnographic research showed strong gains in understanding, motivation, and higher-order thinking. | Limited sample (4 schools); qualitative method restricts statistical generalization. |
| **10.** | Explore critical thinking skills ethnochemical-based on chemistry education students | (Wahyudiati, 2022) | Exploring Chemistry Education Students' Critical Thinking Skills and Ethnochemistry-Based Learning Experiences based on Gender | Journal of Xi'an Shiyou University (Q2) | Female students exhibited higher critical thinking and ethnochemistry-based learning experience levels than males. | Cross-sectional study; lacks intervention and long-term effect analysis. |

| No | 21st century skills integration | Author | Article Titles | Journal | Findings | Limitation |
|---|---|---|---|---|---|---|
| **11.** | Knowing the differences in the application of ethnochemistry toproblem-solving skillsbased on gender | (Wahyudiati, 2024) | The Effect of the Ethnochemistry Approach on Students' Problem-Solving Ability and Chemistry Learning Experiences Based on Gender | Pegem Journal of Education and Instruction (Q3) | Ethnochemistry improved problem-solving and chemistry learning experiences, especially for female students. | Small sample (44 students); short-term duration; limited external validity. |
| **12.** | Analyze chemical literacy pupils using a culturally responsive method combined with ethnochemistry. | (Wardani et al., 2024) | Differentiated Learning: Analysis of Students' Chemical Literacy on Chemical Bonding Material through Culturally Responsive Teaching Approach Integrated with Ethnochemistry | Jurnal Penelitian Pendidikan IPA (S2) | Cultural differentiation in learning increased engagement and conceptual clarity in chemical bonding topics. | Conducted in one institution; lacks diverse participant demographics. |
| **13.** | Development of instruments to measure science literacy | (D. Rahmawati et al., 2025) | Validation of an AI-Based Automatic Assessment System for Scientific Literacy Instruments on Green Chemistry Integrated with Ethnochemistry | Journal of Environment and Sustainability Education (S2) | Validation of AI-based assessment tools showed reliability in evaluating literacy integrated with ethnochemistry. | Only validation phase; not tested in actual classroom teaching. |

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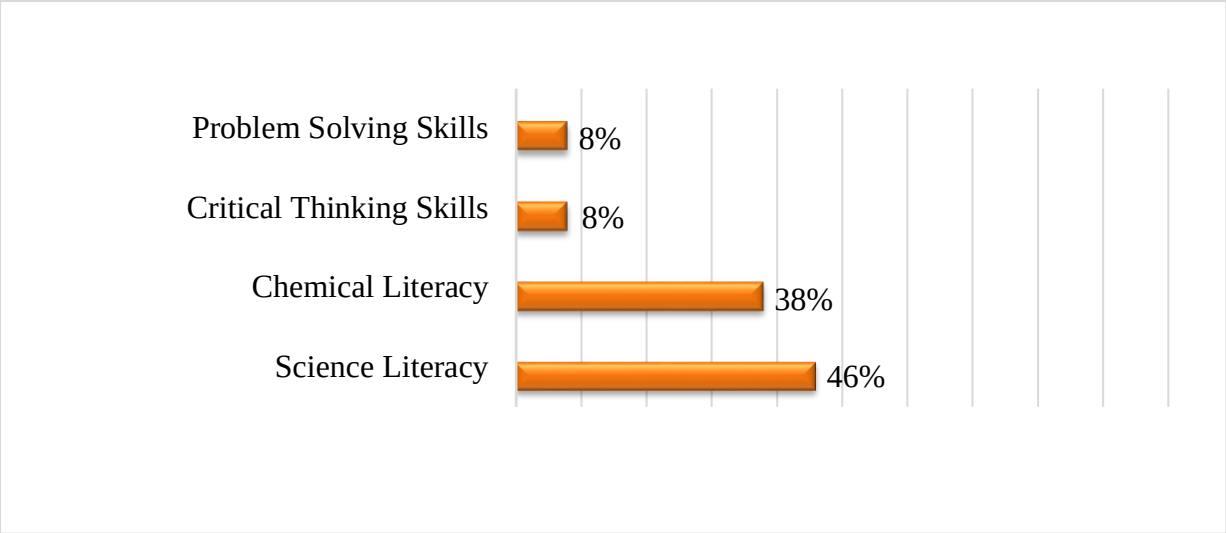


Figure 2. Graph of Percentage of 21st Century Skills Developed Through Ethnochemistry-Based Learning

The synthesis of the thirteen articles reviewed indicates that the application of ethnochemistry in chemistry education significantly contributes to the development of 21st-century skills, particularly in the areas of scientific literacy, chemical literacy, as well as critical thinking and problem-solving skills. The percentage of 21st-century skills that can be developed through 21st-century learning is shown in Figure 1. Scientific literacy is the 21st-century skill with the highest percentage, 46%, because 6 out of the 13 articles support this skill. Chemical literacy follows at 38%, with critical thinking and problem-solving skills each accounting for 8%. Almost all studies agree that the integration of local cultural contexts in learning not only enhances students' conceptual understanding but also strengthens the contextual values relevant to everyday life. By linking chemistry concepts with cultural practices, students find it easier to understand scientific phenomena because they learn from familiar and meaningful experiences. Based on the article review, the following is an explanation of each 21st-century skill supported by ethnochemistry:

**Ethnochemistry in Supporting Scientific Literacy**

PISA results indicate that students' scientific literacy has been ranked in the bottom 10 worldwide over the past 15 years (OECD, 2023). Several studies have shown that ethnochemistry can enhance scientific literacy. Ethnochemistry plays a key role in improving scientific literacy by bridging traditional knowledge with scientific concepts, exploring the potential of natural resources, introducing applicable chemical concepts, and strengthening awareness of sustainability (Sukrisno et al., 2024). Thus, ethnochemistry not only enriches scientific understanding but also broadens the horizon of science education in a more relevant and contextual manner for society.

The improvement in scientific literacy, according to the articles reviewed, is primarily influenced by teaching materials such as e-modules, multimedia Adobe Flash, textbooks, and worksheets containing ethnochemistry. Local wisdom embedded in the worksheets is more practical, helping students learn science. Students can apply their concepts to solve problems related to the Minangkabau culture, thereby improving their scientific literacy (Asda et al., 2023). This aligns with (Heliawati et al., 2022) research, which states that using ethnochemistry-based Adobe Flash multimedia to explore the potential of Gewang seed extract as an anti-cancer agent raises awareness of the importance of recognizing Indonesia's

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biodiversity. Learning materials in the context of local knowledge help students achieve their goals and better understand scientific principles in real life. Ethnochemistry-based textbooks developed for this purpose have great potential to serve as a reference in culturally-based chemistry education (Hendrawani et al., 2025). The increase in students' scientific literacy after receiving the ethnochemistry-based acid-base module further supports the development of scientific literacy (Yanti et al., 2025). Instruments integrated with ethnochemistry to measure scientific literacy have also been developed (D. Rahmawati et al., 2025).. From the review of six articles related to ethnochemistry in supporting scientific literacy, it was found that scientific literacy improves by using various teaching materials integrated with ethnochemistry, and instruments have been developed to measure scientific literacy integrated with ethnochemistry.

**Ethnochemistry in Supporting Chemical Literacy**

Chemical literacy is the ability to understand and apply chemical knowledge in everyday life, including the knowledge, awareness, and effective application of chemistry (Novitasari et al., 2022). Students' chemical literacy in Indonesia is still relatively low, as supported by Harianto et al. (2025) research, which shows that students' chemical literacy is still categorized as insufficient. This is due to the lack of social-cultural involvement in chemistry education, even though many chemistry topics in daily life are related to culture. Ethnochemistry is a learning approach that integrates local knowledge and scientific knowledge (Dewi et al., 2024). Therefore, it is necessary to integrate ethnochemistry into chemistry education to improve chemical literacy.

Several articles reviewed show that the ethnochemistry approach can enhance students' chemical literacy. The implementation of the ethnochemistry-based Sasambo learning model improved chemical literacy (Mutiah et al., 2024). Ethnochemistry-based e-modules can particularly enhance students' chemical literacy, especially in solving environmental issues. This is because e-modules support independent learning, allowing students to research real-world problems (Dewi et al., 2024). The ethnochemistry approach, as shown by students' understanding of the methods of colloid and solution production through experiments, has a positive impact on chemical literacy. This approach encourages the application of scientific methods, making learning relevant and engaging (Ridwan et al., 2025). Differentiated learning integrated with ethnochemistry enhances chemical literacy because learning becomes contextual, meaningful, and aligned with students' readiness. In the context of chemical literacy indicators, students demonstrated the ability to connect chemistry topics with daily life phenomena (Wardani et al., 2024).

**Ethnochemistry in Supporting Critical Thinking Skills**

Various studies using cultural products in learning have shown positive results for critical thinking (H. Sutrisno et al., 2020). This is consistent with the research reviewed. Critical thinking and more positive student attitudes were observed in the application of ethnochemistry-based learning. Female students indicated that they were more interested in learning chemistry because it was integrated with local culture in daily life, making the learning experience more meaningful (Wahyudiati, 2022).

**Ethnochemistry in Supporting Problem-Solving Skills**

Problem-solving ability is one of the essential skills needed to succeed in the 21st century. Prioritizing problem-solving skills in 21st-century learners promotes innovation and creativity, leading to higher academic achievement, success in the workplace, and increased innovation and creativity (Adeoye & Jimoh, 2023). Furthermore, integrating problem-solving skills into education can enhance students' adaptability and decision-making skills (Rusmin et al., 2024).

The ethnochemistry approach integrated into learning is one solution to improve students' problem-solving skills. Ethnochemistry-based learning models significantly improve students' problem-solving abilities (Gultom & Rohaeti, 2024). The research examined the differences in students' problem-solving abilities based on gender. The results showed that there was a gender difference in problem-solving abilities, with females demonstrating better problem-solving skills compared to males (Wahyudiati, 2024).

Methodologically, innovations in integrating educational technology and AI-based assessments, as done by (Yanti et al., 2025) and (D. Rahmawati et al., 2025) show new potential for measuring and enhancing scientific literacy. Entrepreneurship-based (technopreneurship) e-modules and AI-based automatic assessment systems make the evaluation process more objective, efficient, and contextual. This approach opens up significant opportunities to bridge the gap between modern educational technology and local values that have long been separated.

However, despite the positive findings, several research limitations have also been identified. Firstly, most studies are local and contextual, focusing on specific regions such as NTB or Jakarta, so their results are difficult to generalize to other cultural contexts. Secondly, most studies use short-term designs without long-term follow-up to assess knowledge retention or the impact of learning on students' scientific attitudes. Thirdly, research instruments in some studies are limited to questionnaires and student perceptions, without data triangulation through observations or in-depth interviews, which could strengthen the validity of the results.

Furthermore, there are still few studies that specifically explore the influence of demographic variables, such as socio-economic background, gender, and ethnicity, on ethnochemistry-based learning outcomes. Only Wahyudiati's research highlights the gender aspect, while other studies have not explored this factor in depth. Another limitation is the technology and infrastructure aspect, where some studies (Heliawati et al., 2022) and (Dewi et al., 2024) heavily rely on digital tools that may not be available in all schools, particularly in resource-limited areas.

Overall, the findings indicate that ethnochemistry has great potential as a relevant, contextual pedagogical approach that empowers 21st-century students. However, further comprehensive and cross-cultural research is needed, involving mixed-methods methodology to gain a deeper understanding of the impact of ethnochemistry on the cognitive, affective, and social development of students. Expanding the context, extending the research duration, and strengthening the validity of instruments and variable control could make ethnochemistry studies a strong foundation for achieving chemistry education that is culturally rooted yet globally oriented.

## CONCLUSION

Based on the identification and analysis of the articles, the contribution of ethnochemistry in supporting the development of 21st-century skills in the context of education indicates that the 21st-century skills supported by ethnochemistry include scientific literacy, chemical literacy, critical thinking skills, and problem-solving abilities. Scientific literacy (46%) and chemical literacy (38%) have the highest percentages among the others. However, there are still several limitations. Firstly, most of the studies are local and contextual, focusing on specific regions such as NTB or Jakarta, making the results difficult to generalize to other cultural contexts. Secondly, most studies use short-term designs, without long-term follow-up to assess knowledge retention or the impact of learning on students' scientific attitudes. Thirdly, the research instruments in some studies are limited to questionnaires and student perceptions, without data triangulation through observations or in-depth interviews that could strengthen the validity of the results.

## RECOMMENDATIONS

The author recommends that further research be conducted on the integration of ethnochemistry to develop 21st-century skills such as critical thinking, problem-solving, creativity, collaboration, and others, which are still rarely explored. Furthermore, it is necessary to integrate ethnochemistry into the chemistry education curriculum, accommodating the ethnochemistry approach as part of the teaching methods, which can enrich the teaching material with local cultural contexts.

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