JPPIPA 12(11) (2026)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

Development of Ethnochemistry-Based Learning Products for Indonesian High Schools: A Systematic Literature Review

Ni Nyoman Dayuni Purnamasari[1*], Sukisman Purtadi[2]

[1] Master's Program in Department of Chemistry Education, Faculty of Mathematics and Natural Science, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia.
[2] Department of Chemistry Education, Faculty of Mathematics and Natural Science, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia.

Received: May 29, 2026
Revised: August 31, 2026
Accepted: November 10, 2026
Published: November 30, 2026

Corresponding Author:
Ni Nyoman Dayuni Purnamasari
ni2125fmipa.2025@student.uny.ac.id

DOI: 10.29303/jppipa.v12i11.15450

Open Access

© 2026 The Authors. This article is distributed under a (CC-BY License)

Abstract: Indonesia has diverse cultures that can be utilized as contexts for chemistry learning through an ethnochemistry approach. However, studies specifically mapping the development of ethnochemistry-based learning products remain limited. This study aims to analyze the development of ethnochemistry learning products at the senior high school level in Indonesia based on product types, ethnochemistry content and chemistry topics, geographical distribution, learning strategies, and learning outcomes. A Systematic Literature Review (SLR) was conducted by adopting the PRISMA 2020 protocol. Literature was obtained from ERIC, Google Scholar, Scopus, and Semantic Scholar for publications from 2016–2025. Based on the inclusion criteria, 28 articles were selected and analyzed using content analysis. The results show a shift in learning product development from printed to digital formats. Traditional culinary and cultural practices were the most frequently integrated ethnochemistry contents, while acid–base chemistry was the most dominant topic. Cultural content originated from various regions of Indonesia, with Central Java showing the greatest diversity, although its distribution remained uneven. Problem-Based Learning (PBL) was the most frequently used learning model, while learning outcomes predominantly focused on the cognitive domain, particularly scientific literacy. Future research should explore underrepresented cultural regions, more abstract chemistry topics, and affective or psychomotor domains.

Keywords: Chemistry education; Ethnochemistry; Learning product development; Systematic literature review

Introduction

Indonesia is recognized as one of the countries with the highest levels of cultural diversity in the world, reflected in the presence of more than 1,200 ethnic groups and over 694 regional languages that remain actively used in society (Badan Pusat Statistik, 2024). This diversity is manifested in various traditional practices passed down through generations as part of intangible cultural heritage (Eichler, 2021). Practices such as food processing, the use of natural materials, and local technologies contain scientific principles that have the potential to serve as learning resources in education (Sumarni et al., 2021; Lestari et al., 2023). However, local knowledge has not yet been optimally utilized in modern education. Therefore, integrating local culture through an ethnochemistry approach, as part of ethnoscience, is important for connecting community knowledge with scientific concepts in chemistry learning (Hikmawati et al., 2021). This integration aligns with constructivist learning theory, which emphasizes the role of prior knowledge and experience in constructing new understanding (Vygotsky, 1978), as well as culturally responsive teaching, which recognizes the importance of students' cultural backgrounds in creating meaningful learning experiences (Gay, 2010).

Chemistry is often perceived as a difficult subject because its concepts are abstract and require an understanding of three levels of representation: macroscopic, submicroscopic, and symbolic, known as

How to Cite:
Purnamasari, N. N. D., & Purtadi, S. (2026). Development of Ethnochemistry-Based Learning Products for Indonesian High Schools: A Systematic Literature Review. *Jurnal Penelitian Pendidikan IPA*, *12*(11), 22–34. https://doi.org/10.29303/jppipa.v12i11.15450

Johnstone's Triplet (Schmidt, 2021). The implementation of ethnochemistry in learning has often focused primarily on the macroscopic level, while the submicroscopic and symbolic levels have not always been explained in depth. In fact, various traditional and cultural practices are related to chemical concepts that can be explained through all three levels of representation. For example, phenomena observed in cultural practices can be explained at the macroscopic level, then connected to processes occurring at the atomic or molecular level and represented symbolically through chemical formulas, molecular structures, or chemical equations (Rahmawati et al., 2023). Using cultural contexts while connecting these three levels of representation can make chemistry learning more closely related to students' lives and easier to understand (Wahyudiati & Qurniati, 2023).

As chemistry education research continues to develop, various studies have developed ethnochemistry-based learning products, including books, modules, worksheets, videos, and other learning media. Advances in digital technology have also encouraged the transformation of printed learning products into more interactive, innovative, and flexible digital formats. This transformation is important because digital products can integrate text, images, animations, videos, simulations, and interactive activities that can support students' understanding of chemistry concepts, including submicroscopic concepts, while also supporting the characteristics of 21st-century learning (Djarwo et al., 2025). Several previous literature reviews have examined ethnochemistry from different perspectives. Munandar et al. (2024) reviewed various methods and applications of the ethnochemistry approach in chemistry education. Widarti et al. (2025) analyzed trends in ethnoscience-based chemistry learning in Indonesia based on topics, approaches and learning models, learning products, and investigated variables. Meanwhile, Gazali et al. (2025) examined the integration of ethnochemistry into local-wisdom-based science and chemistry teaching at the senior high school level. Although these reviews have provided an overview of the implementation and development of ethnochemistry-based learning, studies specifically analyzing the development of ethnochemistry-based learning products remain limited, particularly regarding the types of products developed, their transformation, and their geographical distribution based on the cultural or traditional content employed. Such mapping is important to provide an overview of the development of ethnochemistry-based learning products in Indonesia while highlighting the diversity of cultures that have been utilized as contexts for chemistry learning. This information can serve as a reference for teachers, researchers, and learning product developers in developing ethnochemistry-based products that are relevant to the local cultural potential of different regions of Indonesia.

Therefore, this study aims to systematically analyze the literature related to the development of learning products using an ethnochemistry approach in chemistry learning at the senior high school level. Specifically, this study aims to examine the transformation of ethnochemistry-based learning product development, analyze the ethnochemistry content and chemistry topics integrated into the products, map the geographical distribution of learning products based on the integrated ethnochemistry content, examine the learning strategies used in the development of ethnochemistry-based learning products, and identify the learning outcomes investigated in studies on the development of ethnochemistry-based learning products.

Method

The analysis of the development of learning products related to ethnochemistry in this study was conducted using a qualitative approach through a literature review. This study applied the Systematic Literature Review (SLR) method, which is a literature review method conducted systematically, transparently, and reproducibly to minimize bias in the selection and synthesis of relevant studies. The implementation process of the SLR in this study adopted the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) 2020 protocol (Page et al., 2021). The systematic review process used in this study is presented in Figure 1.

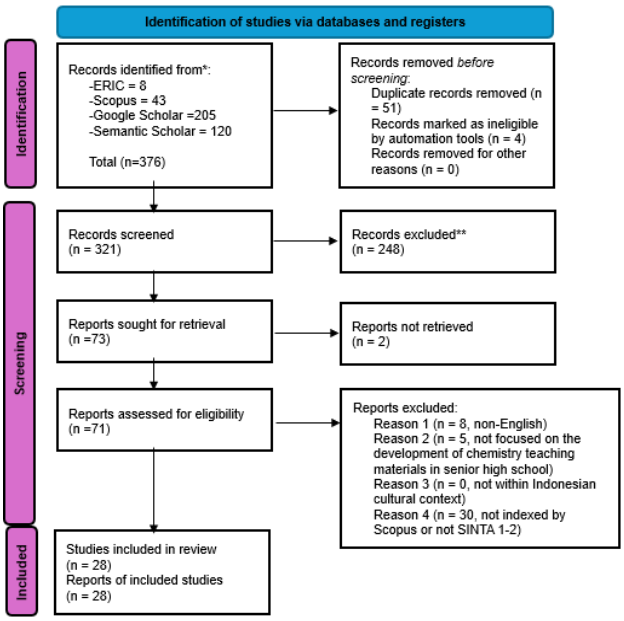


Figure 1. PRISMA 2020 flow protocol

The first stage in this study was identification, which involved searching the literature from various academic databases, including ERIC, Google Scholar, Scopus, and Semantic Scholar, using Boolean operators and keywords as presented in Table 1. The literature search was conducted on April 12, 2026. The initial search resulted in 376 articles published between 2016 and 2025. Subsequently, 55 duplicate articles were removed, leaving 321 articles for the screening stage.

Table 1. Database Search String

Database	String	Results
Google scholar	'development' 'design' AND 'ethnochemistry' 'ethnoscience' 'local wisdom' AND 'chemistry education' 'chemistry learning'	205
Scopus	TITLE-ABS-KEY("Development" AND ("Ethnoscience" OR "Ethnochemistry" OR "Local Wisdom") AND ("Chemistry Education" OR "Chemistry Learning")) AND PUBYEAR > 2015 AND PUBYEAR < 2026	43
Semantic scholar	("development" OR "design") AND ("ethnochemistry" OR "ethnoscience" OR "local wisdom") AND ("chemistry education" OR "Chemistry Learning")	120
ERIC	("development" OR "design") AND ("ethnochemistry" OR "ethnoscience" OR "local wisdom") AND ("chemistry education" OR "chemistry learning")	8

During the screening stage, articles were screened based on their titles and abstracts, resulting in 73 articles relevant to the research topic. Subsequently, the accessibility of the full texts was assessed, and 2 articles were found to be inaccessible in full. Therefore, 71 articles proceeded to the eligibility stage, where their full texts were examined to assess their compliance with the inclusion criteria. At this stage, 43 articles were excluded, consisting of 8 articles that were not written in English, 5 articles that did not focus on the development of ethnochemistry-based learning products for the senior high school level (SMA/MA), including literature review articles, and 30 articles that did not meet the journal indexing or accreditation criteria. The assessment of language and research focus was conducted manually because the databases used did not provide automated filtering based on all of these criteria. Journal indexing status was verified through Scopus and the SCImago Journal & Country Rank (SJR), while the accreditation status of national journals was verified through the SINTA portal of the Ministry of Education, Culture, Research, and Technology. The final stage was the included stage, in which articles meeting all inclusion criteria were selected. The selection process resulted in 28 articles that met the criteria and were included in the analysis.

Subsequently, the 28 articles that met the inclusion criteria were analyzed using content analysis to obtain a descriptive overview of the development of ethnochemistry-based learning products in Indonesia. Information from each article was extracted and categorized based on the types of learning products developed, product transformation, ethnochemistry content and chemistry topics integrated, geographical origins of the cultural or traditional content, learning strategies employed, and learning outcomes examined. The categorized data were then compared to identify patterns, trends, and the distribution of ethnochemistry-based learning products across different regions of Indonesia.

The inclusion criteria in this study were as follows: articles written in English; articles discussing the development of learning products using an ethnochemistry approach at the senior high school level (SMA), such as modules, books, worksheets, videos, and other learning products; development studies examining ethnochemistry contexts or local wisdom in Indonesia; and articles published in Scopus-indexed international journals or national journals accredited at a minimum of SINTA 2.

Result and Discussion

The data obtained from the 28 articles included in this literature review consisted of studies related to the development of learning products based on the ethnochemistry approach implemented in senior high school chemistry learning by integrating Indonesian local culture. A summary of all analyzed articles is presented in Table 2.

Table 2. Results of Articles Included in the Systematic Literature Review

Code article	Author's name, year	Learning products develop	Findings
[1]	Marsila et al. (2025)	E-Module	The e-module was valid, practical, and effective in improving students' understanding of acid–base concepts through the integration of Minangkabau cultural contexts, including gulo saka production, traditional woven fabric dyeing, and Solok rice cultivation.

Code article	Author's name, year	Learning products develop	Findings
[2]	Rosyada et al. (2025)	Book	The Ethno-STEM integrated book was valid and effective in improving chemical literacy and numeracy skills in the context of traditional foods of Pati.
[3]	Yanti et al. (2025)	E-Module	The technopreneurship-based e-module was valid, practical, and effective in improving scientific literacy on redox reaction topics integrated with Batak ethnochemistry.
[4]	Rahmawati et al. (2025)	AI-based Automatic Assessment	The AI-based automatic assessment system was valid for measuring scientific literacy in green chemistry integrated with Javanese ethnochemistry.
[5]	Masturdin et al. (2025)	Module	The contextual module based on ethnographic exploration of Baduy traditional knowledge was valid and effective in contextual based chemistry learning.
[6]	Anwar & Rohman (2025)	Module	The colloid module with a batik waste processing context (4STMD) was valid, practical, and suitable for use in senior high schools.
[7]	Fitri et al. (2025)	Short Video (Reels)	The ethnochemistry short video on the Ketapang Malay tribe was valid as a supplementary learning resource for hydrocarbon topics.
[8]	Tiring & Janggo (2025)	E-Module	The interactive e-module based on the Poto Wua Ta'a tradition was valid and effective in improving conceptual understanding of acid–base topics.
[9]	Zulyanti et al. (2025)	E-Encyclopedia	The local wisdom-based e-encyclopedia (traditional herbal medicine and pottery) was valid and effective in improving conceptual understanding of chemistry.
[10]	Yuendita & Dina et al. (2024)	Book	The Augmented Reality (AR)-based chemical literacy book integrated with Madurese local wisdom was valid and attractive for learning.
[11]	Pebrianti & Suryani et al. (2024)	Module	The PBL-based acid–base module integrated with ethnochemistry was valid, practical, and effective in improving scientific literacy.
[12]	Kusuma & Sumarni (2024)	E-Worksheet	The ethnoscience-integrated e-worksheet was valid and effective in improving critical thinking skills on acid–base topics.
[13]	Irnawati & Rahmawan (2024)	Website	The Weebly-based website containing acid–base ethnochemistry content was valid, practical, and easily accessible as a learning medium.
[14]	Marthin et al. (2024)	Worksheet	The PBL-based worksheet integrated with ethnoscience on acid–base topics was valid and feasible for use in senior high schools.
[15]	Salsabila & Rohaeti (2023)	E-Worksheet	The inquiry-based e-worksheet integrated with Brebes local wisdom was valid and effective in improving conceptual understanding of reaction rates.
[16]	Rumansyah et al. (2023)	E-Magazine	The ethnoscience e-magazine with a wetland context was valid and effective in improving students' critical thinking and scientific literacy.
[17]	Siami et al. (2023)	Worksheet	The worksheet integrated with Semarang batik ethnoscience was valid and effective in improving students' chemical literacy.
[18]	Hanum et al. (2023)	Learning Device (Lesson Plans, Worksheet, Handouts, Test Instruments)	The ethnoscience-based PjBL learning devices (lesson plans, worksheets, handouts, and tests) were valid and effective in improving critical thinking skills.
[19]	Asda (2023)	Worksheet	The PBL-based buffer solution worksheet integrated with the manyiriah tradition ethnochemistry was valid and effective in improving scientific literacy
[20]	Putera (2023).	Domino card game	The domino card game on chemical elements integrated with Madurese herbal medicine ethnochemistry was valid and attractive as a learning medium.

Code article	Author's name, year	Learning products develop	Findings
[21]	Anggreni et al. (2023)	Microblogs	The Malay ethnochemistry-based acid–base microblog was valid for preserving culture and improving conceptual understanding of chemistry.
[22]	Setyorini et al. (2022)	E-Module	The local wisdom-based e-module (traditional beverages) was valid and effective in improving scientific literacy and reading literacy.
[23]	Syahmani et al. (2022)	E-Module	The guided inquiry ethnoscience e-module was valid and effective in improving problem-solving skills on colloid topics using Dayak cultural contexts.
[24]	Tahya et al. (2022)	Module	The Maluku local wisdom-based chemistry module was valid and effective in improving students' science process skills.
[25]	Almubarak & Saadi (2022)	Module	The chemistry representation module with a wetland context was valid, practical, and effective as a learning medium in Kalimantan.
[26]	Syahmani et al. (2022)	E-Magazine	The e-magazine using the SEL approach was valid and effective on colloid topics integrated with Banjar local wisdom.
[27]	Dewi et al. (2020)	Module	The ethnoscience-based acid–base module was valid and effective in improving senior high school students' scientific literacy.
[28]	Sudarmin et al. (2019)	Worksheet	The PBL-based worksheet integrated with green chemistry and ethnoscience was valid and effective in improving higher-order thinking skills.

RQ 1: Transformation and Types of Developed Ethnochemistry Learning Products

The analysis of 28 articles that met the inclusion criteria showed various types of ethnochemistry-based learning products developed in chemistry learning. Studies related to the development of ethnochemistry-based learning products were not found during the 2016–2018 period. This condition was likely influenced by the limitation of article sources, which only included journals accredited at a minimum of SINTA 2. Based on Figure 2, studies began to emerge in 2019–2020 with a focus on conventional printed products, such as modules and worksheets, because they were easier to implement in school learning. In 2022, a shift toward digital learning products began to occur, such as e-modules and e-magazines, with their number exceeding that of printed products. This condition indicates increasing attention from researchers toward the integration of technology in ethnochemistry-based learning, in line with the needs of post-pandemic digital learning and 21st-century learning demands (Ng et al., 2023). Syahmani et al. (2022) explained that e-modules can be accessed through laptops or smartphones and used anytime and anywhere, thereby supporting more flexible and independent learning. The trend of developing digital learning products continued to increase during the 2023–2025 period. In 2023, there were seven articles consisting of three printed products and four digital products. In 2024, the number of studies remained relatively stable, with the development of digital products continuing consistently. The peak development occurred in 2025, with a total of nine articles dominated by digital learning products. This finding indicates an acceleration in the transformation of ethnochemistry-based learning products development toward digital formats.

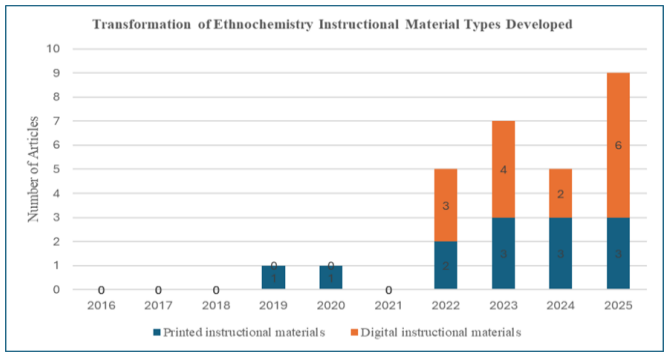


Figure 2. Transformation of developed ethnochemistry learning product types

Based on the overall recapitulation, a total of 28 Based on the overall analysis, the 28 articles produced 28 ethnochemistry-based learning products developed in both printed and digital formats. The learning products showed an equal proportion of printed and digital formats, with each accounting for 50%, or 14 products. The types of learning products developed in digital and printed formats are presented in Figures 2 and 3.

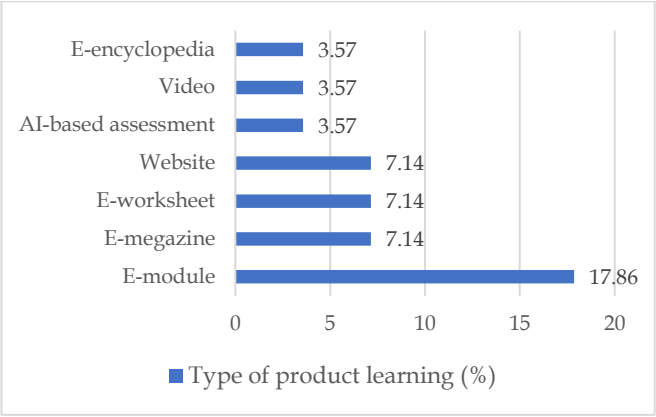


Figure 3. Type of digital ethnochemistry learning products development

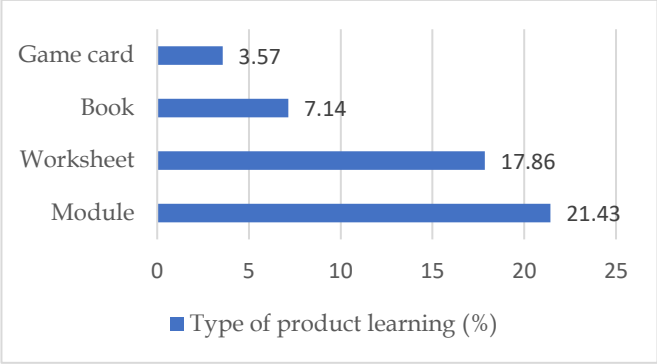


Figure 4. Type of printed ethnochemistry learning products development

The dominance of digital learning products in recent years indicates that researchers have begun to utilize technological advancements to develop chemistry learning that is more innovative, interactive, and contextual. The developed digital products are not limited to e-modules, but also include websites, learning videos, e-encyclopedias, and even artificial intelligence (AI)-based automatic assessment systems. The variety of digital learning products developed reflects researchers' creativity in integrating ethnochemistry content into learning products that are adaptive to students' needs in the digital era (Hasibuan et al., 2026).

Nevertheless, printed learning products continued to be developed until 2025. The dominant printed products were printed modules and worksheets. The dominance of printed products indicates that although digital transformation in education continues to develop, researchers still tend to choose printed formats because they are considered more practical, easier to use in schools with limited technological infrastructure, and more flexible for integration with contextual and hands-on local cultural contexts. From a policy and infrastructure perspective, this condition also reflects an adaptive response to the reality that the equal distribution of educational technology in Indonesia has not yet been optimal (Nurhayati et al., 2025). Printed learning products provide a more inclusive solution because they can be used without dependence on internet connectivity or electronic devices. This is in line with the view that the development of learning products should consider real conditions in the field rather than merely focusing on the idealism of educational digitalization (Hatija, 2024).

RQ 2: Ethnochemistry Content and Chemistry Topics Integrated into Developed Learning Products

Based on the analysis of 28 articles, the integrated ethnochemistry content was classified into five categories, namely traditional culinary (30%), cultural practice (30%), traditional product (22.5%), herbal medicine (12.5%), and general (5%). This distribution reflects the richness of Indonesia's cultural ecosystem as a source of authentic contexts for chemistry learning, as presented in Table 3.

The cultural practice and traditional culinary categories became the most dominant ethnochemistry content, each accounting for 30%, cultural practices such as rice field cultivation, soil pH management, the practice of Menyirih, and traditional wedding customs were widely used to teach acid–base and reaction rate concepts because they are directly related to students' daily experiences. Meanwhile, traditional culinary contexts such as tape, papeda, wedang rempah, and other regional foods were used to explain concepts of chemical reactions, colloids, macromolecules, and redox reactions. The dominance of these two categories indicates that cultural contexts that are applicative and easily observed are more frequently selected in the development of ethnochemistry learning because they can make chemistry concepts more concrete and meaningful (Hikmawati et al., 2021; Wahyudiati & Qurniati, 2023).

The traditional product category (22.5%) includes natural dyeing of woven fabrics and batik, salt production, traditional tattoo ink, and pottery crafts integrated with acid–base, hydrocarbon, colloid, and elemental chemistry concepts. Meanwhile, the herbal medicine category (12.5%) relates the use of bajakah roots and traditional herbal medicine to redox and acid–base concepts. This indicates that ethnochemistry functions not only as a cultural context, but also as a means of connecting chemistry concepts with local practices, traditional health knowledge, and community production activities (Siami et al., 2023; Anwar & Rohman, 2025).

Table 3. Ethnochemistry Content in Learning Product Development

	Ethnochemistry content	Chemistry topics	Article code
Traditional culinary (30%)	Traditional brown sugar production	Acid-base	[1]
	Traditional foods of Pati (nasi gundul, tape gembong, mangut, ndas manyung, and bandeng presto)	Chemical reaction	[2]
	Traditional Batak food "dengke mas naniura"; tempoyak	Redox reaction	[3]
	Tape fermentation	Green chemistry	[4]
	Traditional foods of Brebes (salted eggs, sate blengong, blusder cake)	Reaction rate	[15]
	Acehnese foods (nagasari, muloh, pliek ue)	Macromolecules	[18]
	Traditional Minangkabau foods (sambalado mudo, bika cake)	Acid-base	[19]
	Traditional beverages (wedang rempah, wedang uwuh)	Reaction rate	[22]
	Traditional Dayak foods (kalumpe, juhu umbut rotan)	Colloid	[23]
	Traditional Papuan food (papeda)	Colloid	[24]
	Traditional Banjar food (bubur baayak, gangan humbut, soto banjar)	Colloid	[26]
Cultural practice (30%)	Rice field cultivation and management (soil pH regulation) (terracing), mangroves, and wetlands	Acid-base; reaction rate	[1], [16], [28], [25]
	Menyirih practice	Acid-base	[3], [12], [19], [8], [14], [21]
	Wedding traditions (berinai, tepuk tepung tawar)	Acid-base	[21]
Herbal medicine 12.5%	Batak culture (bajakah root)	Redox reaction	[3]
	Traditional herbal medicine (jamu)	Acid-base	[4], [12], [9], [20]
Traditional product 22.5%	Natural dyeing (woven fabrics, batik) and its processing	Acid-base	[1], [4], [10], [17], [6], [13], [5]
	Use of tree sap for tattoo ink	Colloid	[23]
	Crafts such as pottery	Elemental chemistry	[10], [9]
	Salt production	Acid-base; reaction rate	[10], [15]
	Ketapang Malay products (empty oil palm bunches, damar mata kucing)	Hydrocarbon	[7]
General (5%)	Local culture associated with chemical phenomena (not specifically mentioned)	Acid-base	[11], [27]

Based on the various topics appearing in the ethnochemistry content within the developed learning products, Figure 5 presents the percentage of occurrence of each chemistry topic integrated into the developed learning products.

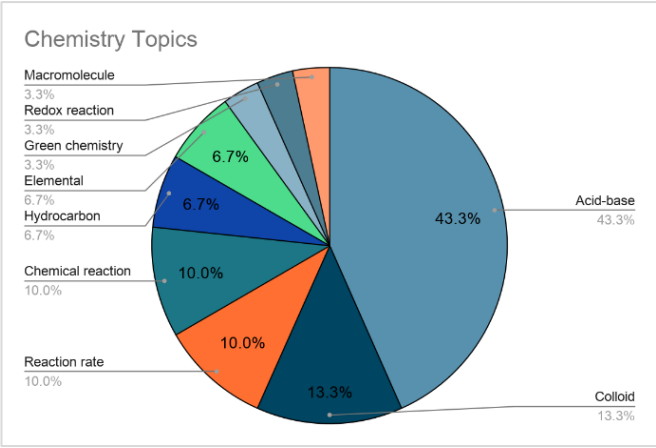


Figure 5. Chemistry topics integrated in develop ethnochemistry learning products

The chemistry topic most frequently integrated into the development of ethnochemistry-based learning products was acid–base chemistry (43.3%), followed by colloids (13.3%), chemical reactions, and reaction rates (10% each). The dominance of acid–base topics indicates that these concepts are the easiest to relate to cultural phenomena and students' daily lives, such as traditional food production, herbal medicine, natural indicators, and soil management. Meanwhile, the high integration of colloid topics shows that many local cultural products and traditional culinary practices involve dispersion systems that can be directly observed by students. Other topics such as hydrocarbons, elemental chemistry, green chemistry, redox reactions, and macromolecules appeared less frequently because these concepts tend to be more abstract and are not always easy to connect with local cultural contexts.

This distribution indicates that the development of ethnochemistry-based learning products is still largely focused on chemistry topics that are contextual, easily observable, and closely related to students' daily experiences. Meanwhile, more abstract chemistry topics such as chemical equilibrium, thermochemistry,

electrochemistry, and chemical bonding are still rarely developed. This condition indicates opportunities for developing ethnochemistry-based learning products on more complex chemistry concepts through visualization approaches or more interactive multimedia.

RQ 3: Geographical Distribution of Ethnochemistry Content in Learning Products

Based on the analysis of the 28 articles, the developed learning products incorporated ethnochemistry content from various regions of Indonesia, including Sumatra, Java, Kalimantan, Nusa Tenggara, and Maluku (Figure 6).

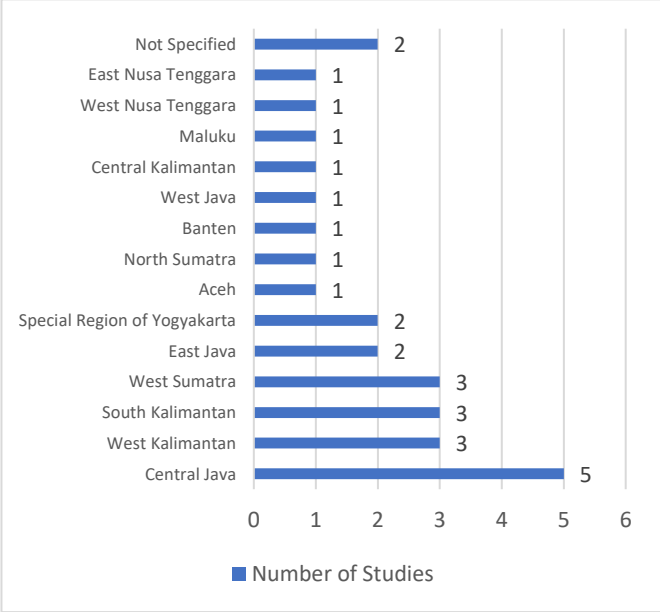


Figure 6. Geographical distribution of ethnochemical content in Indonesia of Studies

Central Java showed the highest diversity of cultural content, including traditional foods from Pati, jamu, tempe fermentation, batik, essential oils, and various Javanese traditions (Rosyada et al., 2025; Rahmawati et al., 2025; Kusuma & Sumarni, 2024; Salsabila & Rohaeti, 2023; Siami et al., 2023). West Sumatra incorporated gulo saka production, traditional textile dyeing, agriculture, and the manyiriah tradition (Marsila et al., 2025; Marthin et al., 2024; Asda, 2023), while West Kalimantan incorporated Malay culture, natural materials, and traditions such as berinai, tepuk tepung tawar, and berkapur sirih (Fitri et al., 2025; Anggreni et al., 2023).

Other regions also demonstrated distinctive cultural content, including wetlands and Banjar traditional foods in South Kalimantan (Rumansyah et al., 2023; Almubarak & Saadi, 2022; Syahmani et al., 2022), salt ponds, pottery, and Madurese batik in East Java (Yuendita & Dina et al., 2024), batik and wedang uwuh in Yogyakarta (Irnawati & Rahmawan, 2024; Setyorini et al., 2022), Baduy natural dyeing practices in Banten (Masturdin et al., 2025), Cirebon batik waste in West Java (Anwar & Rohman, 2025), as well as Batak, Acehnese, Dayak, Maluku, and Nusa Tenggara cultures represented through traditional foods, medicinal plants, handicrafts, cultural practices, and the use of natural materials (Yanti et al., 2025; Hanum et al., 2023; Syahmani et al., 2022; Tahya et al., 2022; Tiring & Janggo, 2025; Dewi et al., 2020).

Although the identified content represents cultures from 14 provinces, its geographical distribution remains uneven. Some regions have relatively diverse cultural content, whereas others are represented by only one cultural context, and some regions have not yet been identified in the 28 analyzed articles. This condition indicates substantial opportunities to explore and integrate local cultural content from regions that remain underrepresented or have not yet been explored as ethnochemistry contexts, thereby expanding the geographical representation of Indonesian cultural diversity in ethnochemistry studies.

RQ 4: Learning Strategies Used in Developed Ethnochemistry Learning Products

The learning strategies identified in the development of learning products using the ethnochemistry approach were often implemented through learning models, approaches, or media, as presented in Table 4.

Table 4. Learning Strategies Used in the Development of Ethnochemistry Learning Products

Learning strategies	Type of learning strategies	(%)
Learning model (42.85%)	Problem based learning (PBL)	14.28
	Inquiry based learning (IBL)	7.14
	Discovery learning (DL)	3.57
	Project based learning (PjBL)	3.57
	Scientific critical thinking (SCT)	3.57
	Chemie im kontext	3.57
Learning approach (32.14%)	STEM	3.57
	Technopreneurship	3.57
	Contextual learning	3.57
	Culturally responsive teaching (CRT)	3.57
	Social emotional learning (SEM)	3.57
Learning media (17.85%)	Instagram	7.14
	Artificial Intelligence (AI)	3.57
	Augmented reality (AR)	3.57
	Weebly	3.57
N/A (7.14%)	Not available	7.14

Based on Table 4, the learning strategies used in the development of learning products with the ethnochemistry approach were categorized into three groups: learning models (42.85%), learning approaches

(32.14%), and learning media (17.85%), while 7.14% of the articles did not explicitly mention the learning strategy used. This finding indicates that most studies on the development of ethnochemistry-based learning products not only focused on integrating local culture as a learning context, but also began to combine it with specific pedagogical frameworks to support more structured and meaningful learning processes.

Among the various learning strategies used in the development of ethnochemistry-based learning products, learning models became the most dominant strategy applied in the implementation of the developed products. Problem-Based Learning (PBL) was the most frequently used model (Pebrianti & Suryani, 2024; Asda, 2023; Marthin et al., 2024; Sudarmin et al., 2019). PBL consists of five learning stages: problem orientation, organizing students for learning, guiding individual or group investigations, developing and presenting work results, and analyzing and evaluating the problem-solving process. Ethnochemistry is often used as the problem context in Problem-Based Learning (PBL), particularly in the first stage, namely problem orientation. This is because presenting problems closely related to students' lives, such as culture and local wisdom, can help students connect chemistry concepts with real phenomena, making learning more meaningful and contextual (Awaluddin, 2025). Asda et al. (2023) presented ethnochemistry at the problem orientation stage by using the Manyiriah tradition of the Minangkabau community as a learning context to help students understand acid–base concepts, particularly buffer solutions. Through this cultural context, students were encouraged to analyze chemical phenomena found in local traditions, making the concepts easier to understand and more relevant to daily life.

In contrast to PBL, which presents ethnochemistry as a context for problem orientation, the Inquiry model tends to present ethnochemistry as a context for scientific investigation and exploration. In the study by Salsabila et al. (2023), local Brebes culture such as salted eggs, sate blengong, and blusder cake was integrated into inquiry activities to help students discover reaction rate concepts. Through observation, discussion, and practical activities, students were encouraged to connect local cultural phenomena with chemistry concepts, making learning more contextual and meaningful. Meanwhile, Project-Based Learning (PjBL) and Discovery Learning (DL) had the same percentage of occurrence in studies on the development of ethnochemistry-based learning products and were still relatively low. The limited use of these two models was likely due to the need for more complex learning activity designs and longer implementation time (Hindun et al., 2025).

Several learning approaches also appeared alongside the use of ethnochemistry in the development of learning products, including STEM, Contextual Learning, Culturally Responsive Teaching (CRT), and Social Emotional Learning (SEL), although their percentages were still relatively low. These findings indicate that the integration of ethnochemistry with various modern learning approaches has only recently begun to develop. Therefore, studies combining ethnochemistry with these approaches are still limited and have not yet been widely developed in chemistry learning product development.

In addition to using learning models and approaches in ethnochemistry learning products development studies, the use of learning media such as Instagram, AI, AR, and Weebly indicates a transformation of ethnochemistry learning toward more interactive digital learning that is adaptive to technological developments. Instagram became the most frequently used medium (7.14%) because it is easily accessible to students and closely related to the lives of today's digital generation. The use of social media in learning enables ethnochemistry content to be presented in a more visual, attractive, and communicative manner (Perez et al., 2023). Furthermore, the use of AI, AR, and website platforms such as Weebly indicates that the development of ethnochemistry-based learning products has begun to utilize modern technologies to improve interactivity, visualization of abstract concepts, and learning flexibility.

RQ5: Learning Outcomes in Ethnochemistry Learning Products Develop

Learning outcomes are the abilities, knowledge, skills, attitudes, or competencies acquired by students after participating in the learning process. Learning domains are generally divided into three categories: the cognitive domain, the affective domain, and the psychomotor domain.

Based on the analysis presented in Table 5, the cognitive domain was the most dominant learning outcome targeted in the development of ethnochemistry-based learning products. Within this domain, scientific literacy was the most frequently developed learning outcome (Marsila, 2025; Pebrianti & Suryani, 2024; Siami et al., 2023; Setyorini et al., 2022; Dewi et al., 2020), followed by conceptual understanding, critical thinking skills (Kusuma & Sumarni, 2024; Hanum et al., 2023; Rumansyah et al., 2023; Sudarmin et al., 2019), numeracy, science process skills, generic science skills, and reading literacy. The dominance of scientific literacy indicates that the development of ethnochemistry-based learning products is aligned with the demands of modern science

education, which emphasizes students' ability to understand scientific phenomena, evaluate information, and apply scientific concepts in everyday life (OECD, 2019).

Table 5. Learning Outcomes in Ethnochemistry Learning Products Developed

Domain	Learning outcomes	(%)
Cognitive domain (82.86%)	Scientific literacy	34.28
	Conceptual understanding	20.00
	Critical thinking skills	11.42
	Numeracy	5.71
	Science process skills	3.03
	Generic science skills	3.03
	Reading literacy	3.03
Affective domain (11.43%)	Motivation	8.57
	Cultural preservation awareness	3.03
Psychomotor domain (0%)	Not available	0.00
N/A (5.71%)	Not available	5.71

Learning outcomes such as scientific literacy were developed through the connection between chemistry concepts and local cultural practices, enabling students to understand that chemistry exists concretely in community life. In addition, the use of local cultural contexts also helps visualize abstract chemistry concepts in a more concrete manner, thereby supporting students' conceptual understanding (Salsabila & Rohaeti, 2023). These learning outcomes were commonly achieved through the implementation of Problem-Based Learning, Inquiry-Based Learning, and contextual approaches. Learning through concepts that are familiar and relevant to students' lives has been shown to help students understand chemistry concepts more easily and increase their engagement in learning (Tiring & Janggo, 2025).

Critical thinking skills also became one of the learning outcomes frequently developed in studies on learning product development using the ethnochemistry approach. These skills were generally developed through learning models emphasizing analysis and problem-solving processes, such as PBL and Scientific Critical Thinking (SCT). In learning with the ethnochemistry approach, students not only study chemistry concepts, but are also encouraged to analyze the relationship between cultural practices and scientific concepts more deeply. This finding indicates that the integration of ethnochemistry can encourage students to think more reflectively, analytically, and critically about cultural phenomena encountered in daily life (Januarti et al., 2024; Rumansyah et al., 2023).

In addition, the affective domain appeared in relatively limited numbers through outcomes such as motivation and cultural preservation awareness. This indicates that studies on the development of learning products using the ethnochemistry approach are still more oriented toward cognitive aspects than affective or psychomotor domains. In fact, ethnochemistry learning has great potential to develop scientific attitudes (Singh & Chibuye, 2016), cultural awareness (Rahmawati & Ridwan, 2017), and practical skills through contextual activities and local cultural practices. Therefore, future studies need to further explore the development of ethnochemistry-based learning products that not only focus on improving cognitive abilities, but also support students' affective and psychomotor development in a more holistic manner.

Conclusion

Based on the review findings, the development of ethnochemistry learning products in Indonesia has shifted from printed products toward digital products, although printed products continue to be developed. The most frequently incorporated ethnochemistry content consists of traditional culinary practices and cultural practices, while acid–base chemistry is the most dominant chemistry topic. Geographically, ethnochemistry content has been drawn from various regions of Indonesia, with Central Java showing the highest diversity of cultural content, although the distribution remains uneven, with some regions still underrepresented or not yet represented. Problem-Based Learning (PBL) is the most frequently used learning model, while the learning outcomes examined are predominantly focused on the cognitive domain, particularly scientific literacy. Future research should expand the exploration of cultural content from regions that are underrepresented or have not yet been explored, address more abstract chemistry topics, and investigate learning outcomes in the affective and psychomotor domains.

Acknowledgments

The author would like to express sincere gratitude to Prof. Antuni Wiyarsi, M.Si. and Dr. Erfan Priyambodo, M.Si. for their valuable guidance and assistance throughout the process of conducting this systematic literature review research.

Author Contributions

Research design, N.N.D.P. and S.P.; article searching and screening, N.N.D.P.; data collection, N.N.D.P.; data analysis, N.N.D.P.; interpretation of findings, N.N.D.P.; writing original draft preparation, N.N.D.P.; supervision and guidance throughout the research process, S.P. All authors have read and approved the published version of the manuscript.

Funding

This study received no external funding.

Conflicts of Interest

The authors declare no conflict of interest.

References

Almubarak, A., & Saadi, P. (2022). Validity, practicality, effectiveness: Wetland contexted-chemical representation module as a media for learning. *Journal of Mathematics Science and Computer Education, 2*(1), 56–72. https://doi.org/10.20527/jmscedu.v2i1.5067

Anggreni, U. D., Hadiarti, D., & Fadhilah, R. (2023). Development of the acid-base microblogs based on Malay ethnochemistry to preserve culture. *Jurnal Penelitian Pendidikan IPA, 9*(8), 6067–6075. https://doi.org/10.29303/jppipa.v9i8.4300

Anwar, S., & Rohman, I. (2025). Development of colloid system module context "Batik Waste Treatment" using four steps teaching material development method. *Jurnal Penelitian Pendidikan IPA, 11*(8), 406–414. https://doi.org/10.29303/jppipa.v11i8.11310

Asda, V. D. (2023). Development of buffer solution students' worksheet based on problem based learning with ethnochemistry to improve students' science literacy ability. *Jurnal Penelitian Pendidikan IPA, 9*(7), 5220–5227. https://doi.org/10.29303/jppipa.v9i7.4369

Awaluddin, R. (2025). Penerapan Model Problem Based Learning (PBL) Berbasis Kearifan Lokal pada Materi Pencemaran Lingkungan Untuk Meningkatkan Pemahaman Siswa Kelas X di SMAN 2 Bolo. *Jurnal Jendela Pendidikan*, *5*(02), 312-321. https://doi.org/10.57008/jjp.v5i02.1340

Badan Pusat Statistik. (2024). *Profil suku dan keragaman bahasa daerah hasil long form sensus penduduk 2020*. BPS-Statistics Indonesia.

Dewi, C. A., Martini, Z. G., Rahmand, N., Zulhariadi, M., Wicaksono, A. T., & Astutik, T. P. (2020). The development of ethnoscience based acid-base modules to improve students' scientific literacy ability. *International Journal of Innovation, Creativity and Change*, *14*(1), 1013-1028. https://doi.org/10.36681/tused.2021.88

Djarwo, C. F., Inggamer, M. M., Rumbrapuk, A. J., & Astuti, N. (2025). Analisis literasi digital berbasis etnosains dalam pembelajaran kimia untuk meningkatkan pemahaman konsep dan motivasi belajar mahasiswa. *Jurnal Pendidikan Dan Pembelajaran IPA Indonesia, 15*(1), 62-77. https://doi.org/10.23887/jppii.v15i1.93346

Eichler, J. (2021). Intangible cultural heritage, inequalities and participation: Who decides on heritage? *International Journal of Human Rights, 25*(5), 793–814. https://doi.org/10.1080/13642987.2020.1822821

Fitri, L., Fadhillah, R., & Hadiarti, D. (2025). Development of ethnosciene reels of Ketapang Malay tribe as supplementary learning resources on hydrocarbon compounds. *Jurnal Penelitian Pendidikan IPA, 11*(2), 131–137. https://doi.org/10.29303/jppipa.v11i2.8595

Gay, G. (2010). *Culturally Responsive Teaching: Theory, Research, and Practice*. Teachers College Press.

Gazali, Z., & Andriani, R. (2025). Integrasi etnokimia dalam pengajaran IPA: Analisis literatur sistematis pada pendekatan berbasis kearifan lokal di SMA. *Jurnal Pendidikan MIPA, 15*(4), 1843–1853. https://doi.org/10.37630/jpm.v15i4.3783

Hanum, L., Hasan, M., Pada, A. U. T., Rahmatan, H., Rahmayani, R. F. I., Elisa, E., & Yusrizal, Y. (2023). Development of learning devices based on ethnoscience project-based learning to improve students' critical thinking skills. *Jurnal Pendidikan Sains Indonesia, 11*(2), 288–305. https://doi.org/10.24815/jpsi.v11i2.28294

Hasibuan, L. J., Erna, M., & Susilawati, S. (2026). Implementasi Media Pembelajaran Interaktif Terintegrasi Etnokimia Melayu Riau Pada Proses Pembelajaran Sebagai Strategi Untuk Meningkatkan Kemampuan Literasi Kimia Peserta Didik. *Eduproxima Jurnal Ilmiah Pendidikan Ipa*, *8*(1), 592–601. https://doi.org/10.29100/.v8i1.8729

Hatija, M. (2024). Evolusi Perangkat Pembelajaran Dalam Dunia Pendidikan Modern. *Jurnal Andi Djemma*, *7*(1), 51-57. https://doi.org/10.35914/jad.v7i1.2601

Hikmawati, H., Suastra, I. W., & Pujani, N. M. (2021). Ethnoscience-based science learning model to develop critical thinking ability and local cultural concern for junior high school students. *Journal of Physics: Conference Series, 1816*(1), 012073. https://doi.org/10.1088/1742-6596/1816/1/012073

Hindun, I., Wahyuni, S., & Nurwidodo, N. (2025). Fundamental question determination procedures and project planning in PjBL at Muhammadiyah high schools. *Research and Development in Education (RaDEn)*, *5*(1), 475-491. https://doi.org/10.22219/raden.v5i1.40029

Irnawati, I., & Rahmawan, S. (2024). Development of Weebly-based website learning media containing ethnochemical acid-base material. *Prisma Sains: Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram, 12*(2), 316–327. https://doi.org/10.33394/j-ps.v12i2.10279

Kusuma, I. A., & Sumarni, W. (2024). Development of ethnoscience integrated e-worksheet in acid base materials to improve critical thinking skill. *Edusains, 16*(2), 98–109. https://doi.org/10.15408/es.v13i2.34136

Lestari, N., Paidi, & Suyanto, S. (2023). A systematic literature review about local wisdom and

sustainability: Contribution and recommendation to science education. *Eurasia Journal of Mathematics, Science and Technology Education, 20*(2). https://doi.org/10.29333/ejmste/14152

Marsila, N., Yerimadesi, Alizar, & Andromeda. (2025). Development of an acid-base e-module based on guided discovery learning with ethnoscience content to improve literacy and numeracy. *Jurnal Penelitian Pendidikan IPA, 11*(8), 1125–1135. https://doi.org/10.29303/jppipa.v11i8.12439

Marthin, E. F., Oktavia, B., & Kurniawati, D. (2024). Development of problem-based learning student worksheet integrated with ethnoscience on acid-base material. *Jurnal Penelitian Pendidikan IPA, 10*(7), 3886–3893. https://doi.org/10.29303/jppipa.v10i7.7930

Masturdin, M., Paristiowati, M., & Yusmaniar, Y. (2025). Integrating Baduy traditional knowledge using ethnographic exploration into the development of context-based chemistry learning. *EduChemia: Jurnal Kimia dan Pendidikan, 10*(2). https://doi.org/10.62870/educhemia.v10i2.35755

Munandar, H., Thayban, T., & Kurniawati, E. (2024). Pendekatan etnokimia dalam pendidikan kimia: Literature review terhadap berbagai metode dan penerapannya. *Pentagon: Jurnal Matematika dan Ilmu Pengetahuan Alam, 2*(2), 56–64. https://doi.org/10.62383/pentagon.v2i2.200

Ng, D. T. K., Leung, J. K. L., Su, J., Ng, R. C. W., & Chu, S. K. W. (2023). Teachers' AI digital competencies and twenty-first century skills in the post-pandemic world. *Educational technology research and development*, *71*(1), 137. https://doi.org/10.1007/s11423-023-10203-6.

Nurhayati, S., Septikasari, D., Judijanto, L., Susanto, D., Tarrapa', S., Sudadi, Setiyana, R., Willdahlia, A. G., Ramli, A., & Zamroni. (2025). *Paradigma baru dalam pendidikan abad 21*. Yogyakarta: Green Pustaka Indonesia.

OECD. (2019). *PISA 2018 assessment and analytical framework*. Paris: OECD Publishing. https://doi.org/10.1787/b25efab8-en

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., & Mulrow, C. D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ, 372*. https://doi.org/10.1136/bmj.n71

Pebrianti, P., & Suryani, O. (2024). Development of the acid-base module based on problem based learning with ethnochemistry to improve students science literacy ability. *Jurnal Penelitian Pendidikan IPA, 10*(8), 4634–4640. https://doi.org/10.29303/jppipa.v10i8.8582

Perez, E., Manca, S., Fernández-Pascual, R., & Mc Guckin, C. (2023). A systematic review of social media as a teaching and learning tool in higher education: A theoretical grounding perspective. *Education and Information Technologies, 28*(9), 11921–11950. https://doi.org/10.1007/s10639-023-11647-2

Putera, D. B. R. A. (2023). Development of integrated elements chemical domino card game with ethnochemistry Madura jamu ingredients. *IJIS Edu: Indonesian Journal of Integrated Science Education, 5*(1), 39–47. http://dx.doi.org/10.29300/ijisedu.v5i1.10481

Rahmawati, D., Yamtinah, S., Shidiq, A. S., Widiarti, H. R., & Wiyarsi, A. (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, 3*(2), 215–222. https://doi.org/10.62672/joease.v3i2.70

Rahmawati, Y., & Ridwan, A. (2017). Empowering students' chemistry learning: The integration of ethnochemistry in culturally responsive teaching. *Chemistry: Bulgarian Journal of Science Education*, *26*(6), 813-830.

Rahmawati, Y., Mardiah, A., Taylor, E., Taylor, P. C., & Ridwan, A. (2023). Chemistry learning through culturally responsive transformative teaching (CRTT): Educating Indonesian high school students for cultural sustainability. *Sustainability, 15*(8), 6925. https://doi.org/10.3390/su15086925

Rosyada, A., Sumarni, W., Nuswowati, M., & Niyamae, A. N. (2025). Ethno-STEM-integrated enriched chemistry book to equip chemical and numeracy literacy. *Journal of Innovation in Educational and Cultural Research, 6*(1), 125–135. https://doi.org/10.46843/jiecr.v6i1.1930

Rumansyah, Hamid, A., Aufa, M. N., Isnawati, & Kusuma, A. E. (2023). Development of wetland ethnoscience e-magazine based on scientific critical thinking model to improve students' critical thinking skills and scientific literacy. *Jurnal Penelitian Pendidikan IPA, 9*(11), 9403-9409.https://doi.org/10.29303/jppipa.v9i11.5093

Salsabila, E., & Rohaeti, E. (2023). Inquiry-based e-worksheet with local wisdom of Brebes Central Java for high school students' understanding of reaction rates. *Jurnal Pendidikan Kimia Indonesia, 7*(2), 69–78. https://doi.org/10.23887/jpki.v7i2.69256

Schmidt, J. B. (2021). Helping students connect the macroscopic level to the molecular level. *Journal of Food Science Education, 21*(1), e20228. https://doi.org/10.1111/1541-4329.12232

Setyorini, L., Haryani, S., & Susilaningsih, E. (2022). Development of e-module based on local wisdom to improve science literacy and reading literacy. *Jurnal Pendidikan Kimia, 14*(1), 28–38. https://doi.org/10.24114/jpkim.v14i1.32948

Siami, F., Sumarni, W., Sudarmin, S., & Harjono, H. (2023). Development of integrated LKPD ethno-science batik Semarang to improve students' chemical literacy. *Jurnal Penelitian Pendidikan IPA, 9*(10), 7784–7792. https://doi.org/10.29303/jppipa.v9i10.3604

Singh, I. S., & Chibuye, B. (2016). Effect of Ethnochemistry Practices on Secondary School Students' Attitude towards Chemistry. *Journal of Education and Practice*, *7*(17), 44-56. Retrieved from https://files.eric.ed.gov/fulltext/EJ1105254.pdf

Sudarmin, S., Zahro, L., Pujiastuti, S. E., Asyhar, R., Zaenuri, Z., & Rosita, A. (2019). The development of PBL-based worksheets integrated with green chemistry and ethnoscience to improve students' thinking skills. *Jurnal Pendidikan IPA Indonesia, 8*(4), 492–499. https://doi.org/10.15294/jpii.v8i4.17546

Sumarni, W., Sudarmin, S., Sumarti, S. S., & Kadarwati, S. (2021). Indigenous knowledge of Indonesian traditional medicines in science teaching and learning using a science–technology–engineering–mathematics (STEM) approach. *Cultural Studies of Science Education, 17*(2), 467–510. https://doi.org/10.1007/s11422-021-10067-3

Syahmani, S., Iriani, R., Riana, S., & Bakti, I. (2022). E-magazine development with social emotional learning approach on colloid material in context of local wisdom. *Tadris: Jurnal Keguruan dan Ilmu Tarbiyah, 7*(2), 289–304. https://doi.org/10.24042/tadris.v7i2.11442

Syahmani, S., Rahmatilah, J., Winarti, A., Kusasi, M., Iriani, R., & Prasetyo, Y. D. (2022). Development of guided inquiry lesson based on ethnoscience e-modules to improve students' problem-solving ability in chemistry class. *Journal of Innovation in Educational and Cultural Research, 3*(4), 670–682. https://doi.org/10.46843/jiecr.v3i4.363

Tahya, D., Dahoklory, F. S., & Dahoklory, S. R. (2022). The development of local wisdom-based chemistry modules to improve students' science process skills. *Jurnal Penelitian Pendidikan IPA, 8*(2), 731–739. https://doi.org/10.29303/jppipa.v8i2.1424

Tiring, S. S. N. D., & Janggo, W. O. (2025). Contextualizing acid–base chemistry learning through local wisdom: Development of an interactive e-module based on the Poto Wua Ta'a tradition in Indonesia. *AL-ISHLAH: Jurnal Pendidikan, 17*(4), 8151–8160. https://doi.org/10.35445/alishlah.v17i4.8643

Vygotsky, L. S. (1978). *Mind in Society: The Development of Higher Psychological Processes*. Harvard University Press.

Wahyudiati, D., & Qurniati, D. (2023). Ethnochemistry: Exploring the potential of Sasak and Javanese local wisdom as a source of chemistry learning to improve the learning outcomes of pre-service teachers. *Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education), 11*(1), 12–24. https://doi.org/10.24815/jpsi.v11i1.26790

Widarti, H. R., Wiyarsi, A., Yamtinah, S., Siddiq, A. S., Sari, M. E. F., Fauziah, P. N., & Rokhim, D. A. (2025). Analysis of content development in chemical materials related to ethnoscience: A review. *Journal of Education and Learning (EduLearn), 19*(1), 422–430. Retrieved from http://edulearn.intelektual.org/index.php/EduLearn/article/view/21210

Yanti, F., Simangunsong, A. D., Sitinjak, E. K., Pane, E. P., & Septiani, N. T. (2025). Development of technopreneurship-based e-modules for ethnochemistry, redox, and science literacy. *Aptisi Transactions on Technopreneurship (ATT), 7*(2), 469–480. https://doi.org/10.34306/att.v7i2.517

Yuendita, D., & Dina, D. (2024). Development of chemical literacy book on local wisdom of Madura culture based on augmented reality (AR). *Jurnal Penelitian Pendidikan IPA, 10*(1), 346–359. https://doi.org/10.29303/jppipa.v10i1.5689

Zulyanti, Fadhilah, R., & Kurniawan, R. A. (2025). Enhancing chemistry learning with a local wisdom-based e-encyclopedia for high school students. *Jurnal Penelitian Pendidikan IPA, 11*(3), 715–722. https://doi.org/10.29303/jppipa.v11i3.10086