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The Chemistry Behind Papeda: Reconstruction of Local Knowledge on Sago Processing (*Metroxylon sp.*) of the Jayapura Community as a Basis for STEM-Based Chemistry Learning in High Schools

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Abstract

Chemistry learning in high schools still faces challenges in connecting abstract concepts with everyday life phenomena, making the learning less contextual. Although ethnoscience has been widely integrated into education, studies that reconstruct local knowledge into chemical concepts as a basis for developing Science, Technology, Engineering, and Mathematics (STEM)-based learning are still limited, particularly in the processing of sago in Papua. This research aims to reconstruct the local knowledge of the Jayapura community regarding the cultivation and processing of sago (*Metroxylon sp.*) into chemical concepts and map it into the STEM-based chemistry learning framework in high schools. The research uses a descriptive qualitative approach with informants selected through purposive sampling, including traditional leaders, sago farmers, and the community. Data were collected through observation, in-depth interviews, and documentation, and then analysed using the Miles, Huberman, and Saldaña model. The analysis involved data reduction, coding, categorisation, identification of recurring themes, and interpretation of relationships between community practices and relevant scientific concepts, which were subsequently synthesised into the reconstruction framework. The research results identified five main themes, namely local knowledge about sago cultivation, processing sago into papeda, transformation of traditional technology, socio-cultural values, and reconstruction of chemical concepts and the STEM framework. The reconstruction identified chemical concepts related to carbohydrate structure and transformation, filtration, sedimentation, decantation, gelatinisation, and viscosity. These concepts were derived by interpreting observed community practices and were subsequently related to established scientific explanations, rather than through experimental investigation of biochemical pathways. The resulting framework maps community knowledge and practices onto relevant chemical concepts and STEM components, providing an empirically grounded reconstruction of the relationship between indigenous practices, scientific interpretation, and chemistry learning. This research provides a qualitative reconstruction framework that connects community cultural practices, chemical concepts, and the STEM framework as a basis for developing contextual chemistry learning in high schools and strengthens the integration of ethnoscience in chemistry education.

Keywords: Chemistry concept reconstruction; Ethnoscience; Local knowledge; Sago (*Metroxylon sp.*); STEM.

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INTRODUCTION

Chemistry learning in the 21st century is no longer solely orientated towards mastering concepts, but also directed towards developing critical thinking skills (Facione, 1990), problem-solving abilities (Polya, 1957), collaboration, and communication through the active construction of knowledge (Driver et al., 1994). This shift in orientation aligns with global demands that emphasise the importance of science literacy, creativity, and evidence-based

decision-making in facing various life challenges (Hadinugrahaningsih et al., 2017; OECD, 2023; UNESCO, 2021). Consequently, chemistry education is expected not to stop at the mastery of scientific concepts, but to be able to relate these concepts to the everyday context of the students, making the learning process more meaningful.

Although these demands have been widely voiced, the reality on the ground shows that chemistry education in schools is still dominated by the delivery of abstract concepts, making it difficult for students to understand the connection between chemical phenomena and everyday life. This difficulty is closely related to the characteristics of chemistry, which require the ability to connect macroscopic, submicroscopic, and symbolic representations, as explained in Johnstone's representation model (Johnstone, 1991; Taber, 2018; Talanquer, 2011). When these three representations fail to be connected, learning tends to shift towards rote memorisation of concepts rather than meaningful understanding, making it difficult for students to apply chemical concepts to explain phenomena they encounter in their surroundings.

One of the approaches that is highly recommended to address this issue is context-based chemistry learning, which places phenomena close to the students' lives as the starting point for learning, so that chemistry concepts are learned through authentic and relevant experiences. Gilbert (2006) emphasises that this approach helps students build connections between scientific concepts and their applications in real life. In line with that, the synthesis by Bennett et al., (2007) of various experimental studies on the context-based and Science-Technology-Society (STS) approaches shows that both approaches consistently improve students' attitudes towards science, with conceptual understanding equivalent to conventional learning. Context-based learning also enhances students' motivation, conceptual understanding, and ability to transfer chemical knowledge to various life situations (Broman et al., 2015). In Indonesia, (Masturdin et al., 2025) reported similar findings, namely that the use of traditional knowledge of the Baduy community as a learning context results in a more meaningful learning experience compared to conventional learning.

In a diverse society like Indonesia, context-based learning becomes increasingly relevant when integrated with local knowledge (local knowledge or indigenous knowledge), which is the result of the community's interaction with its environment, developed through long experiences and passed down through generations as part of the cultural system. Local knowledge is viewed as a learning resource that can bridge students' understanding of scientific concepts and does not have to be positioned as a system of knowledge that contradicts modern science (Snively & Corsiglia, 2001). The integration of indigenous knowledge in chemistry education increases student engagement because scientific concepts are learned through cultural practices they are already familiar with (Anor et al., 2022). These findings are reinforced by (Chibuye & Singh, 2024), who demonstrate that a chemistry curriculum based on local knowledge can enhance the relevance of learning while strengthening the connection between school science and community life.

The development of culture-based chemistry education has subsequently been supported by approaches such as Culturally Responsive Science Education and Culturally Responsive Transformative Teaching (CRTT), which place students' culture as an integral part of the learning process rather than merely as an illustration. Through this approach, culture becomes the foundation for building scientific understanding while simultaneously strengthening students' identity with science. Studies have shown that CRTT in chemistry learning can enhance critical thinking, collaboration, communication, appreciation of local culture, and science literacy (Rahmawati et al., 2020a). These findings affirm that the integration of local culture in chemistry education not only enhances the quality of learning but also plays a role in preserving local knowledge as part of contextual science education.

In recent years, the integration of ethnoscience with the Science, Technology, Engineering, and Mathematics (STEM) approach has been increasingly developed as a strategy

to produce contextual and problem-oriented learning (Bybee, 2013; Sanders, 2009). The integration of STEM provides students with the opportunity to connect scientific concepts with the application of technology, engineering processes, and mathematical reasoning in solving real-world problems. The effectiveness of this approach has been supported by various empirical studies. One of them is the meta-analysis conducted by Wahono et al., (2020) on 54 studies in the Asian region, which shows that the consistent application of STEM has a moderate positive impact on learning outcomes, higher-order thinking skills, and student motivation. Accordingly, Ethno-STEM has developed by integrating local cultural practices with science, technology, engineering, and mathematics, enabling students to connect scientific concepts with authentic cultural contexts and problem-solving processes. Various studies show that the integration of ethnoscience and STEM can enhance students' science literacy, critical thinking skills, creativity, and problem-solving abilities because the learning takes place within authentic cultural contexts that are close to their lives (Gultom & Rohaeti, 2024; Hikmawati et al., 2021; Sumarni et al., 2021).

In general, previous research on the application of ethnoscience in chemistry education can be categorised into three main directions. Some studies focus on the development of learning tools, such as modules, media, and Student Worksheets (LKPD) based on ethnoscience or Ethno-STEM (Parmin et al., 2019). This trend is reinforced by the recent findings of Wakhidyah et al., (2026), who tested the validity of the Ethno-STEM-based IPA module and proved that the module is valid for use in enhancing students' higher-order thinking skills. Another study emphasises the implementation of culturally responsive teaching through the Culturally Responsive Transformative Teaching approach (Rahmawati et al., 2020b), while a third research group examines the integration of indigenous knowledge into the science curriculum and learning (Heliawati et al., 2022; Irawati et al., 2023; Munandar et al., 2024; Zidny & Eilks, 2020). Although differing in focus, these three lines of research show a common conclusion that local knowledge can enhance the meaningfulness of learning when properly integrated into the learning process.

Nevertheless, a critical review of these studies shows that most of the research still stops at the stage of learning implementation or device development, while the systematic process of reconstructing local knowledge into chemical concepts remains less explicitly addressed. Local knowledge is generally used as a context or example in learning, and the analytical relationship between community cultural practices, chemical concepts, and STEM components is not always made explicit. As a result, the connection between local culture and scientific concepts remains implicit, making it difficult to serve as a conceptual basis in the development of teaching materials or the design of chemistry learning.

Research gaps are also evident in the cultural contexts that are the subjects of study. Most ethnoscience research in Indonesia is conducted on local cultures in Nusa Tenggara, such as the Sasak tribe and the SASAMBO culture in Lombok and Sumbawa (Dewi et al., 2019; Hakim et al., 2020; Mashami et al., 2023), as well as in Sumatra (Usman et al., 2019), with a broader overview mapped through a national thematic review (Kasi et al., 2021). In recent years, ethnoscience studies in Papua have begun to show progress. Budiarti et al., (2026), for example, explored the elements of ethnoscience in the rural communities of Jayapura and examined the perceptions of junior high school students regarding the integration of local knowledge in science education. These findings reinforce the potential of Papuan local knowledge as a source of science learning while also indicating the growing attention to the Papuan cultural context in science education research. However, the cited studies primarily address the identification of ethnoscientific elements, perceptions, or educational integration, rather than the systematic reconstruction of local practices into chemistry concepts and their subsequent mapping into STEM. This gap becomes important to study considering that the Papuan community possesses a wealth of local knowledge developed through long interactions with the natural environment, one of which is reflected in the cultivation and processing system of sago (*Metroxylon sp.*) that

not only serves as a staple food source but also as part of the cultural identity of the indigenous Papuan people (Sidiq et al., 2021; Susanto et al., 2024). These activities involve various processes that can potentially be reconstructed into chemical concepts, such as carbohydrate structure and properties, filtration, sedimentation, decantation, gelatinisation, viscosity, and other relevant chemical phenomena. Thus, the gap is not merely the limited study of sago or Jayapura, but the absence of an explicit reconstruction pathway that systematically connects community practices, their interpretation into chemical concepts, and their mapping into the STEM framework.

Based on these conditions, this research offers novelty in the development of a model for reconstructing the local knowledge of the Jayapura community regarding the cultivation and processing of sago into chemical concepts, which are then mapped into the framework of Science, Technology, Engineering, and Mathematics (STEM). The novelty therefore lies in the structure of the reconstruction model, which systematically links community cultural practices, researcher interpretation, established chemical concepts, STEM components, and relevant high school chemistry learning materials. This research aims to reconstruct the local knowledge of the Jayapura community regarding the cultivation and processing of sago (*Metroxylon sp.*) into chemical concepts and map the reconstruction results into a STEM-based chemistry learning framework in high schools.

METHOD

Research Design and Setting

This study employed a descriptive qualitative approach to reconstruct the local knowledge of the Jayapura community regarding sago (*Metroxylon* sp.) cultivation and processing into relevant chemical concepts within the Science, Technology, Engineering, and Mathematics (STEM) framework (Creswell & Creswell, 2018). This approach was adopted to explore community knowledge, experiences, and cultural practices in their natural context and interpret their relationships with established scientific concepts. The study focused on reconstructing local knowledge and mapping the resulting chemical concepts into the STEM framework rather than experimentally investigating chemical processes or evaluating classroom learning outcomes.

The research was conducted in Jayapura Regency, Papua, Indonesia, where sago cultivation and processing remain integral to the community's social, economic, and cultural life. This setting provided a relevant context for examining traditional knowledge and practices associated with sago cultivation, starch extraction, and papeda preparation.

Research Participants and Sampling

The informants consisted of traditional leaders, sago farmers, and community members selected through purposive sampling based on their direct knowledge, experience, and involvement in sago cultivation and processing. Traditional leaders were selected for their recognized cultural authority and knowledge of local sago-related practices and traditions. Sago farmers were selected based on their direct and sustained experience in cultivating and processing sago, while community members were selected for their familiarity with and direct experience of sago processing practices.

These informant groups provided complementary perspectives on the cultural, practical, and social dimensions of sago-related knowledge. Their experiences contributed to understanding traditional cultivation practices, processing procedures, technological adaptations, and the socio-cultural significance of sago. All informants participated voluntarily after providing verbal informed consent, and their identities were kept confidential.

Data Collection

Data were collected through direct observation, semi-structured in-depth interviews, and documentation to explore community practices, knowledge, experiences, and cultural perspectives related to sago cultivation and processing. Direct observation provided

information on the practices involved in sago cultivation and processing, while semi-structured interviews explored informants' knowledge, experiences, and cultural interpretations of these practices. Documentation provided additional records of the activities examined during the study.

The information obtained through these techniques served as the empirical basis for identifying recurring patterns of local knowledge and interpreting their relationships with relevant scientific concepts. Community practices observed or reported by informants were distinguished from the scientific interpretations subsequently developed by the researchers to maintain clarity between empirical findings and scientific reconstruction.

Data Analysis and Scientific Reconstruction

Data were analyzed using the interactive model of Miles, Huberman, & Saldaña (2014), involving data condensation, data presentation, and conclusion drawing and verification. Interview data were transcribed and coded to identify meaningful units, which were subsequently grouped into categories and developed into research themes. The analytical process involved data condensation, open coding, axial coding, selective coding, scientific interpretation, and STEM integration, as summarized in Table 1.

Data condensation involved selecting and organizing information relevant to sago cultivation, processing practices, technological adaptations, and socio-cultural values. Open coding was used to identify meaningful units within the qualitative data, axial coding to connect related codes into categories, and selective coding to organize these categories into broader research themes. These coding procedures supported the systematic organization and interpretation of the qualitative findings within the interactive data analysis process.

The identified themes provided the basis for reconstructing relevant chemical concepts associated with sago cultivation and processing. Scientific reconstruction involved interpreting documented community practices using established scientific explanations while distinguishing empirical community knowledge from the researchers' scientific interpretations. For example, the separation of fibrous residues from starch-containing liquid, the settling of starch particles, and the preparation of papeda through heating were interpreted in relation to filtration, sedimentation, and starch gelatinization, respectively. These concepts were reconstructed through the interpretation of qualitative evidence and established scientific knowledge rather than direct experimental investigation of molecular or biochemical processes.

The reconstructed concepts were subsequently mapped onto the four STEM components. Science represented the chemical and scientific principles associated with sago cultivation and processing. Technology referred to traditional and modern tools used in these activities. Engineering was interpreted through the organization and adaptation of processing procedures, while Mathematics was identified through quantitative considerations embedded in community practices, including estimates of starch yields. This mapping established relationships among community knowledge, reconstructed chemical concepts, technological applications, practical problem-solving, and quantitative reasoning. The resulting Ethno-STEM framework provided a conceptual basis for developing contextual chemistry learning in high schools rather than an empirically tested learning intervention.

Table 1. Research Data Analysis Process

Stages	Analysis Activities	Outputs
Data Condensation	Selecting and simplifying interview data	Organised transcript
Open Coding	Coding units of meaning	Code list
Axial Coding	Connecting codes into categories	Categories
Selective Coding	Developing categories into themes	Research themes
Interpretation	Reconstructing themes into chemical concepts	Chemical concepts
STEM Integration	Mapping chemical concepts to Science, Technology, Engineering, Mathematics	Ethno-STEM framework

Trustworthiness of the Research

The trustworthiness of the study was addressed using the criteria of credibility, transferability, dependability, and confirmability proposed by Lincoln & Guba (1985). Credibility was supported through source triangulation, technique triangulation, and member checking. Source triangulation involved comparing information obtained from traditional leaders, sago farmers, and community members, while technique triangulation involved comparing interview findings with observational data and field documentation. Member checking was conducted by reconfirming the interpretation of research themes with selected key informants to ensure consistency between the findings and their experiences.

Dependability and confirmability were supported by maintaining an audit trail comprising field notes, interview transcripts, and photographic documentation. These records provided a basis for tracing the relationship between the collected data and the resulting interpretations. Transferability was considered in relation to the social, cultural, and environmental context of sago cultivation and processing in Jayapura Regency. To maintain transparency, the reconstructed chemical concepts and their STEM mapping were distinguished from the empirical findings and presented as scientific interpretations grounded in qualitative evidence rather than experimentally verified chemical mechanisms or validated classroom learning outcomes.

RESULTS AND DISCUSSION

The results of this study reveal that sago (*Metroxylon sp.*) is not only an important food resource for the Jayapura community but also represents a local knowledge system involving cultivation practices, traditional processing techniques, technological development, and socio-cultural values. The findings were obtained through observations, semi-structured interviews, and documentation involving traditional leaders, sago farmers, and community members. The analysis shows that knowledge of sago is transmitted across generations and is reflected in both traditional practices and contemporary adaptations in sago processing. Furthermore, these practices contain scientific principles that can be reconstructed into relevant chemistry concepts and integrated into the STEM framework. The findings are presented through five interconnected aspects: local knowledge of sago cultivation, local knowledge of processing sago into papeda, the transformation of traditional technology into modern technology, the socio-cultural value of sago processing, and the reconstruction of local knowledge into chemistry concepts and STEM.

Sago Cultivation: Local Knowledge and Its Socio-Cultural Dimensions

The findings from observations and interviews indicate that the Jayapura community possesses extensive local knowledge concerning the cultivation and management of sago (*Metroxylon sp.*), which is transmitted across generations through direct participation in daily activities. This knowledge encompasses seed selection, planting, maintenance, harvesting, resource conservation, and the utilization of sago as an important food and cultural resource. The findings further indicate that sago cultivation is not solely oriented toward food production but is closely associated with resource sustainability, cultural identity, food security, and intergenerational knowledge transmission.

Regarding seed selection and planting, informants explained that new sago plants are generally obtained from young shoots growing around the parent tree. Suitable shoots are separated from the parent plant and transferred to locations considered appropriate for sago growth, particularly moist or water-rich areas. After planting, maintenance is conducted through relatively simple practices, primarily by removing weeds and other plants that may interfere with the growth of sago clumps. These practices indicate that the community relies on experiential knowledge to identify suitable planting conditions and maintain sago growth without intensive cultivation practices. Resource sustainability is also embedded in the community's harvesting practices. A sago farmer explained:

"If we cut down one, we plant two or three trees at most. Must. So that our culture will not be lost."

The statement indicates that harvesting is followed by replanting as a customary practice to maintain the availability of sago for future generations. Replanting is therefore not merely an agricultural activity but also reflects the community's awareness of resource continuity. The practice connects the utilization of sago resources with a cultural responsibility to prevent the loss of a resource that is closely associated with community life.

The community also possesses experiential knowledge regarding the appropriate time for harvesting sago. Informants explained that sago is harvested when the plant has reached an appropriate level of maturity, which can be recognized through morphological characteristics, particularly the condition of the plant before flowering. Harvesting too early is believed to result in lower starch yields, whereas trees that have passed the optimal harvesting period may also produce less starch because stored reserves are associated with reproductive development. A traditional leader emphasized this knowledge:

"If they cut down the young sago, their yield will be less. So people often forbid it, if it's still young, don't cut it down. Let it be until it is old, then it can be cut down."

Informants further reported that a mature trunk harvested under favorable conditions may produce approximately ten to twelve sacks of starch, whereas harvesting outside the preferred period may result in lower yields. These observations demonstrate an empirical relationship established by the community between plant maturity and expected starch production. This information is treated here as empirical local knowledge; the biological and chemical interpretation of starch accumulation is presented separately in the scientific reconstruction section.

Sago also has an important socio-cultural role. Informants described sago as a staple food and a symbol of cultural identity. Papeda, prepared from sago starch, is associated with traditional gatherings, welcoming guests, customary activities, and cultural ceremonies. One informant stated:

"If there is a traditional event, sago is the most important. It feels incomplete without papeda."

This statement illustrates that papeda functions not merely as food but also as a cultural representation of community identity. The presence of sago and papeda in traditional activities demonstrates the continuing connection between food practices and cultural values within the community. Sago therefore contributes simultaneously to food security and the preservation of cultural identity.

The findings also show that sago-related activities provide an informal context for intergenerational learning. Children and younger community members accompany their parents or older family members to sago-growing areas, where they observe, assist with, and gradually practice different stages of cultivation and processing. Informants did not describe a formal educational process or specific ritual for transferring this knowledge. Instead, knowledge is acquired through repeated participation and observation in everyday activities. This form of experiential learning enables practical knowledge concerning sago cultivation, harvesting, processing, and utilization to be maintained within the community.

Sago activities also involve cooperation among community members, particularly during cultivation, harvesting, and processing. Such activities provide opportunities for interaction and collective participation, strengthening social relationships while simultaneously facilitating the transfer of practical knowledge. Thus, the socio-cultural significance of sago can be identified through several interconnected values, including food security, cultural identity, knowledge inheritance, social togetherness, and participation in traditional activities.

Overall, the findings indicate that local knowledge of sago cultivation is embedded within a broader socio-cultural system. Knowledge of propagation, maintenance, harvesting, and resource conservation is closely connected to the community's dependence on sago as a food resource and its symbolic role in cultural life. The continuity of these practices is supported by experiential learning and direct participation across generations. This finding provides an important foundation for the subsequent reconstruction of sago cultivation and processing practices into scientific and chemical concepts, as the community's experiential knowledge contains observable processes that can be interpreted through a scientific perspective.

Table 2. Synthesis of Local Knowledge and Socio-Cultural Values of Sago Cultivation

Aspect	Findings	Data Evidence	Interpretation
Seed selection and propagation	Seedlings are obtained from young shoots around the parent tree	Informants described selecting and transferring suitable shoots	Local knowledge of vegetative propagation
Plant maintenance	Weeds and interfering plants are removed around sago clumps	Observation and farmer interviews	Experiential knowledge for supporting plant growth
Resource conservation	Replanting is conducted after harvesting	"If we cut down one, we plant two or three trees..."	Local conservation practice and resource sustainability
Harvest timing	Sago is harvested before flowering at an appropriate maturity stage	Informants associated maturity with starch yield	Empirical knowledge of plant maturity and starch accumulation
Food security	Sago and papeda serve as important food resources	Community interviews	Sago as a source of food security
Cultural identity	Papeda is important in traditional gatherings and ceremonies	"It feels incomplete without papeda"	Sago as a cultural symbol
Knowledge inheritance	Younger generations learn through direct participation	Children accompany parents to sago-growing areas	Informal intergenerational knowledge transmission
Social togetherness	Cultivation and processing involve collective participation	Observation and interviews	Sago activities strengthen community interaction

The findings demonstrate that the Jayapura community's knowledge of sago cultivation encompasses practical decisions concerning seedling selection, growing conditions, plant maintenance, harvesting, and resource regeneration. Rather than being based on formal scientific measurement, this knowledge has developed through repeated observation and experience and has been transmitted across generations. The community's ability to recognize suitable harvesting conditions and manage sago regeneration illustrates how local knowledge can provide practical guidance for the sustainable use of biological resources. From an ethnoscientific perspective, such knowledge represents an experiential system developed through continuous interaction between the community and its environment (Aikenhead & Michell, 2011; Snively & Corsiglia, 2001).

The community's practice of determining harvest time according to plant maturity, particularly before flowering, can be interpreted from the perspective of plant physiology and carbohydrate metabolism. Sago accumulates photosynthetic products in the stem, particularly in the pith, in the form of starch that functions as an energy reserve. As the plant progresses toward its reproductive phase, stored carbohydrates may be increasingly utilized to support

reproductive development. Consequently, the community's observation that harvesting at an appropriate pre-flowering stage produces greater starch yields is consistent with the general biological relationship between plant developmental stage and carbohydrate allocation. However, this interpretation should be understood as a scientific reconstruction of the community's empirical knowledge rather than as a direct experimental determination of starch content in this study.

The use of morphological characteristics to determine harvesting readiness is particularly significant because it demonstrates how the community has developed practical indicators without relying on laboratory instruments. Through repeated observation, community members have established an experiential relationship between visible plant characteristics, maturity, and expected starch yield. Such practices illustrate the epistemological value of local knowledge, in which knowledge is generated, tested, and refined through long-term interaction with the natural environment. This finding supports previous research showing that indigenous or local knowledge can contain empirically grounded understandings that may be reconstructed and connected with scientific concepts (Aikenhead & Michell, 2011; Snively & Corsiglia, 2001).

Replanting practices after harvesting further demonstrate that local knowledge extends beyond production toward resource continuity. Planting new shoots contributes to the regeneration of sago stands and supports the continued availability of the resource for future use. This practice is consistent with the broader principle of sustainable resource management and is particularly relevant to food security in communities that depend on sago as an important food resource. This interpretation is consistent with Sidiq et al. (2022), who emphasized the importance of sustainable sago production in supporting food security among Indigenous communities in Papua. Thus, the community's cultivation practices demonstrate that resource utilization and conservation are not necessarily separate activities but can operate as interconnected components of a local management system.

The findings also provide an important basis for chemistry education. Although the community does not conceptualize sago cultivation using formal chemical terminology, several practices can be reconstructed through concepts related to photosynthesis, carbohydrate formation, starch accumulation, and the role of carbohydrates as energy reserves. This reconstruction provides an opportunity to connect chemistry concepts with phenomena that are familiar to students in regions where sago is part of everyday life. As noted by Chibuye & Singh (2024), local knowledge can provide a meaningful context for science learning when its underlying concepts are systematically identified and reconstructed. In the present study, the contribution extends beyond identifying local knowledge by organizing the knowledge into chemical concepts that can subsequently be connected to STEM-based chemistry learning. Such contextualization can help students relate abstract concepts of carbohydrates and macromolecules to observable practices and cultural experiences within their local environment.

Sago Processing into Papeda: Local Knowledge and Chemical Reconstruction

The observations and interviews revealed a relatively consistent sequence of sago processing, beginning with trunk preparation and pith extraction, followed by grating, water-assisted extraction, filtration, settling, separation of the upper water layer, and preparation of papeda. Although some stages have incorporated modern equipment, the basic sequence remains recognizable within the community. Informants also emphasized that the quality and quantity of starch depend on both harvesting conditions and subsequent processing practices.

The harvested trunk is first prepared and the pith is separated. The pith is then grated or crushed to facilitate starch extraction. Informants explained that this activity was traditionally performed manually, whereas grating machines are now increasingly used. The grated pith is mixed with water, after which the resulting material is processed to obtain starch-containing liquid. The mixture is passed through a filtering material to separate the fibrous residues. The

filtrate is then allowed to stand until starch accumulates at the bottom, after which the upper water layer is carefully removed.

The community's processing practices therefore demonstrate knowledge of a sequential procedure for obtaining usable starch. At this stage, the description represents the empirical findings obtained from observation and interviews; the scientific interpretation of the individual separation processes is addressed in the following section. This distinction is important because informants described the procedures through practical experience rather than formal chemical terminology. Technological change is particularly evident in the transition from manual grating to mechanical equipment. One informant stated:

> *"In the past, it was still manual. Now, we use graters and alkon machines."*

Another informant explained:

> *"Now it's mostly just machines. In the past, it was manual, but now some use an alkon."*

These statements indicate that modern equipment has been incorporated into an existing local processing sequence. The use of machines primarily reduces physical effort and facilitates faster processing, while the community continues to determine the overall sequence of processing based on established experience. When modern equipment is unavailable because of breakdown or other constraints, traditional manual procedures remain practically relevant. The final stage involves cooking the extracted starch to prepare papeda. Informants described papeda as an important food in everyday life and cultural activities. Sago starch may also be prepared through other methods, including roasting. One informant stated:

> *"If you make papeda, the flour can also be roasted. Roasting it in leaves is also possible."*

This finding illustrates that local knowledge includes not only a procedure for extracting starch but also knowledge concerning its subsequent utilization in different food preparations. The empirical practices described above were subsequently reconstructed using relevant scientific and chemical concepts. The reconstruction distinguishes between what was directly observed or reported by informants and the scientific interpretation assigned to those practices.

During pith preparation and grating, mechanical disruption breaks down plant tissue and facilitates the release of starch-containing material. The addition of water then assists the dispersion and release of starch particles from the disrupted pith matrix. These processes provide a scientific basis for discussing plant tissue disruption, starch dispersion, and the physical behavior of starch-containing suspensions.

Filtration represents the clearest material-separation process identified in the empirical data. The community passes the water-containing sago mixture through a filtering material to retain relatively coarse fibrous residues while allowing the liquid fraction containing dispersed starch particles to pass through. Scientifically, this practice can be reconstructed as filtration, a separation process involving a porous medium. The empirical practice is therefore directly connected to a formal chemistry concept without assuming that the community itself uses the term "filtration."

After filtration, the suspension is allowed to stand until starch accumulates at the bottom of the container. This practice can be scientifically reconstructed as sedimentation, because suspended particles settle under gravitational influence. The subsequent careful removal of the upper water layer can be reconstructed as decantation. Importantly, sedimentation and decantation should be treated as a connected separation sequence rather than discussed repeatedly as separate findings.

The preparation of *papeda* provides another clear scientific reconstruction. When the starch suspension is heated in the presence of water and stirred, its appearance and consistency change from a relatively fluid suspension to a thick, translucent, and cohesive material. This

observable transformation can be interpreted through starch gelatinization, during which starch granules absorb water and swell as temperature increases, producing changes in the physical properties of the starch system, including increased viscosity. The behavior can also provide a context for discussing the roles of amylose and amylopectin in starch functionality (Tako et al., 2014). However, these molecular-level explanations constitute scientific reconstructions of the observed practice; the present study did not experimentally measure molecular changes during *papeda* preparation.

The relationship between sago maturity and starch yield can also be interpreted scientifically in relation to carbohydrate accumulation. Sago stores photosynthetic products in the stem, particularly in the pith, in the form of starch. The community's preference for harvesting at a particular maturity stage can therefore be related to the biological allocation and accumulation of stored carbohydrates. This interpretation should be distinguished from direct measurement because the present study did not experimentally determine starch concentration at different developmental stages.

The reconstruction consequently identifies a set of chemical and scientific concepts that are directly connected to the observed practices: starch accumulation, carbohydrate structure, mechanical disruption, dispersion, filtration, sedimentation, decantation, gelatinization, and viscosity. Diffusion is not retained as a principal reconstructed concept because the present empirical findings do not provide sufficiently direct evidence to support its inclusion.

Table 3. Reconstruction of Empirical Sago Practices into Scientific Concepts

Empirical practice	Evidence from the practice	Scientific reconstruction	Chemical/scientific concept
Pith grating	Pith is cut, grated, or crushed	Mechanical disruption facilitates release of starch-containing material	Mechanical disruption
Mixing with water	Grated pith is mixed with water	Starch particles are dispersed in an aqueous medium	Dispersion
Filtering	Fibrous residues are retained by filtering material	Solid residues are separated from the liquid fraction	Filtration
Allowing the suspension to stand	Starch accumulates at the bottom	Suspended particles settle under gravity	Sedimentation
Removing upper water	Upper liquid is carefully removed	Liquid is separated from deposited material	Decantation
Cooking starch	Starch suspension becomes thick and cohesive	Starch granules swell and change during heating in water	Gelatinization
Increased thickness of *papeda*	Cooked product becomes viscous	Heating changes starch-system properties	Viscosity
Harvesting at maturity	Community associates maturity with starch yield	Stored carbohydrates are associated with plant developmental stage	Starch accumulation/carbohydrate metabolism

Integration of Reconstructed Knowledge into the STEM Framework

Based on the observations, interviews, and qualitative data analysis, the local practices of the Jayapura community in cultivating and processing sago (*Metroxylon sp.*) were reconstructed into chemistry concepts and subsequently mapped onto the Science, Technology, Engineering, and Mathematics (STEM) framework. The reconstruction was conducted by identifying scientific meanings embedded in community practices while retaining their original cultural context. The resulting framework connects local practices with chemistry concepts and

the four STEM components, providing a basis for contextual chemistry learning in high schools.

The reconstruction identified several chemistry concepts associated with sago cultivation and processing, including starch accumulation, carbohydrate structure, filtration, sedimentation, decantation, gelatinization, and viscosity. These concepts emerge from observable practices rather than from formal scientific explanations provided by the community. For example, the community's knowledge of harvesting sago at an appropriate maturity stage can be related to starch accumulation, while the processes of washing, filtering, settling, and separating sago starch can be interpreted through filtration, sedimentation, and decantation. The transformation of starch into papeda through heating provides a context for understanding gelatinization and changes in viscosity. These connections demonstrate that local practices can serve as empirical starting points for reconstructing scientific concepts without replacing the community's original knowledge system.

The mapping of these findings into STEM is presented in Figure 1. The Science component represents the chemical and scientific phenomena identified through the reconstruction of sago cultivation and processing. These include starch accumulation in the sago stem, carbohydrate characteristics, separation of starch from plant residues, sedimentation, decantation, and starch gelatinization during papeda preparation. The scientific interpretation provides the conceptual foundation for explaining why particular processing stages are performed and how observable changes occur during sago processing.

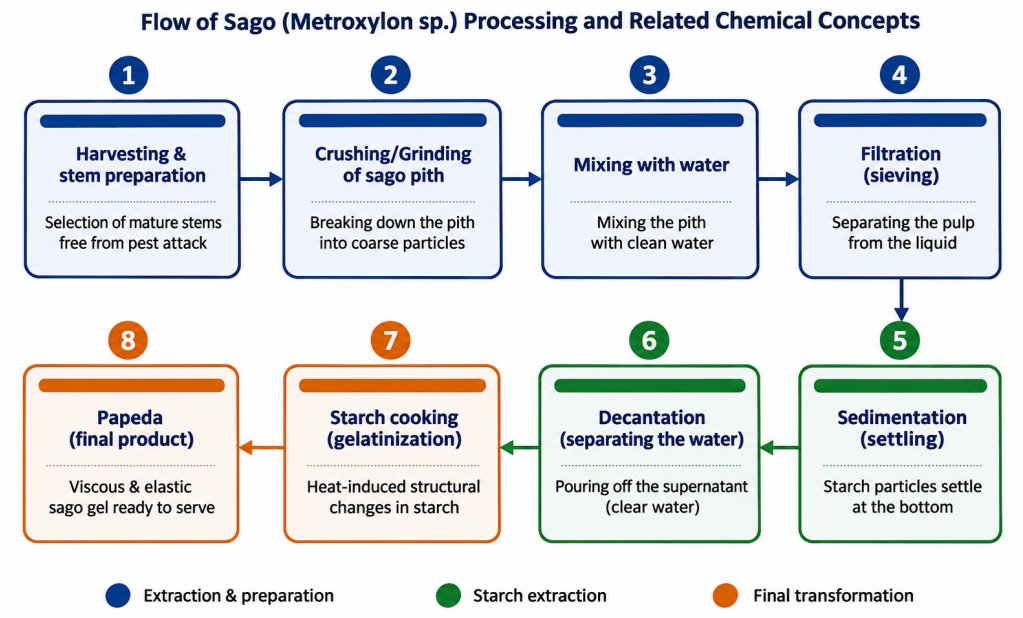

Figure 1. Flowchart of the stages of sago processing (*Metroxylon sp.*)

The Technology component is represented by the tools used in sago cultivation and processing. Traditional tools, such as machetes, axes, manual graters, and filtering materials, reflect technologies developed according to local needs and environmental conditions. The community has also adopted modern equipment, including grating machines and alkon water pumps, particularly to reduce physical effort and improve processing efficiency. The coexistence of traditional and modern equipment demonstrates that technology within the local knowledge system is dynamic and can adapt to changing needs while maintaining the fundamental processing sequence.

The Engineering component can be identified in the community's organization and adaptation of processing procedures to obtain usable sago starch and produce papeda. Decisions concerning the appropriate harvesting stage, preparation of the pith, sequence of extraction and separation, and cooking procedure demonstrate practical optimization based on accumulated experience. These practices can be interpreted as forms of experience-based

problem solving in which procedures are maintained, modified, or adapted according to the desired processing outcomes. However, this engineering interpretation refers to the functional organization of community practices rather than to a formal engineering design process.

The Mathematics component is represented by quantitative considerations that occur in sago cultivation and processing, particularly those reported by informants, such as estimating starch yield and comparing the amount of product obtained under different harvesting conditions. For example, informants estimated that a sago trunk harvested under favorable conditions could produce approximately ten to twelve sacks of starch. Such estimates demonstrate the use of quantitative reasoning in evaluating production outcomes. The mathematical dimension identified in this study is therefore primarily practical and embedded in everyday decision-making rather than expressed through formal mathematical calculations.

The resulting STEM integration demonstrates that local knowledge does not function merely as a cultural illustration added to chemistry learning. Instead, the reconstruction establishes a relationship among community practices, scientific concepts, technological applications, practical problem solving, and quantitative reasoning. This finding is consistent with the integrated STEM perspective proposed by Kelley & Knowles (2016), in which STEM learning is strengthened when scientific knowledge is connected with technological and engineering practices. It also supports the view that local knowledge can provide an authentic context for science learning when its underlying concepts and practices are systematically reconstructed (Aikenhead & Michell, 2011; Chibuye & Singh, 2024).

The framework developed in this study can be represented as a sequence from local knowledge → chemical reconstruction → STEM integration → contextual chemistry learning. In this sequence, local practices constitute the empirical starting point, chemical reconstruction provides the scientific interpretation, and STEM mapping identifies the connections among scientific concepts, technologies, practical problem solving, and quantitative reasoning. The resulting framework provides a conceptual basis for developing culturally responsive chemistry learning materials in high schools.

The potential educational implication of this framework is that sago cultivation and papeda processing can be used as contextual phenomena for chemistry learning. Students can investigate starch accumulation, mixture separation, filtration, sedimentation, decantation, gelatinization, and viscosity through practices that are familiar within the local community. The framework may subsequently be developed into STEM-based learning activities, teaching materials, student worksheets, or project-oriented learning designs. However, the effectiveness of these learning applications requires further empirical testing, as the present study focuses on the reconstruction and mapping of local knowledge rather than the implementation of a specific learning model.

Research Contribution and Local Knowledge Reconstruction Model

This study provides a conceptual contribution to chemistry education by developing a reconstruction model that connects the local knowledge of the Jayapura community regarding sago (*Metroxylon* sp.) cultivation and processing with chemistry concepts and the STEM framework. The model consists of six interconnected stages: (1) identification of local community knowledge, (2) identification and documentation of cultural practices, (3) scientific reconstruction of the identified practices, (4) reconstruction into relevant chemistry concepts, (5) mapping of the reconstructed concepts into the STEM framework, and (6) potential application in STEM-based contextual chemistry learning.

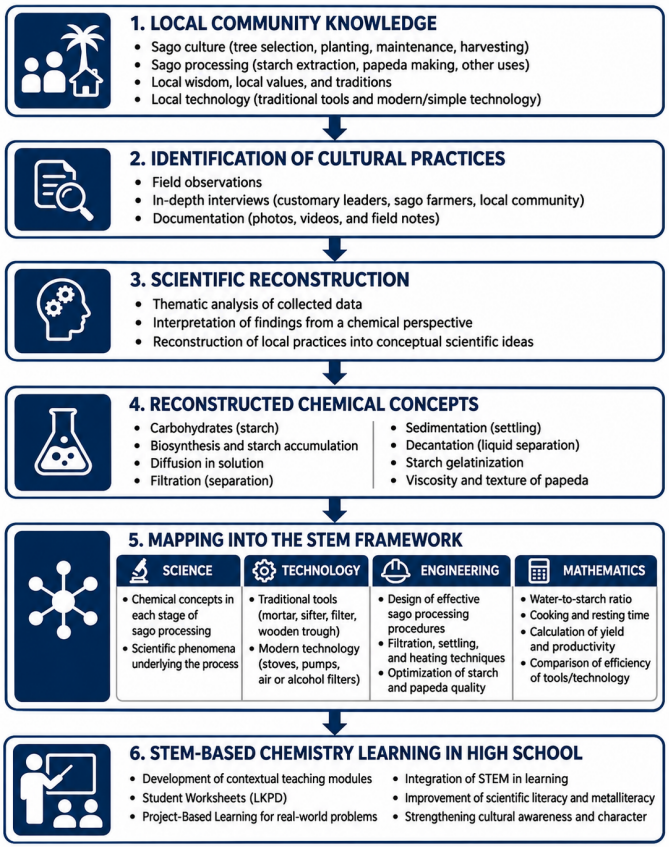

Figure 2. Model of Local Knowledge Reconstruction of Sago Processing into Chemistry Concepts for STEM-Based Chemistry Learning in High School.

As shown in Figure 2, the model establishes a systematic pathway that begins with local knowledge, continues through the identification of cultural practices, scientific reconstruction, and the development of relevant chemistry concepts, and then proceeds to STEM integration and potential application in contextual chemistry learning. This pathway positions local knowledge not merely as an illustration in chemistry learning but as an empirical starting point for identifying and reconstructing scientific concepts while maintaining its cultural context.

The model contributes theoretically by strengthening the connection between ethnoscience and STEM-based chemistry education. Practically, it can provide a basis for developing teaching modules, student worksheets, learning media, and STEM-oriented learning activities using sago cultivation and *papeda* processing as contextual resources. The framework also supports contextual and culturally responsive learning by connecting chemistry concepts with students' social, cultural, and environmental surroundings (Badan Standar dan Asesmen Pendidikan, 2022).

The main novelty of this study lies in the systematic reconstruction of local knowledge into chemistry concepts and their subsequent integration into the STEM framework. The resulting model provides a potential pathway for adapting local cultural practices into chemistry learning contexts in other regions. However, the present study focuses on knowledge reconstruction and conceptual mapping; therefore, the effectiveness of the proposed framework in improving chemistry learning outcomes, scientific literacy, or STEM competencies requires further empirical validation.

CONCLUSION

The findings indicate that the Jayapura community's local knowledge of sago (*Metroxylon sp.*) cultivation and processing is associated with relevant chemical concepts, including starch biosynthesis, carbohydrate structure, diffusion, filtration, sedimentation, decantation, gelatinization, viscosity, and amylose–amylopectin interactions. These practices

were systematically mapped into the STEM framework, encompassing scientific principles, local technology, engineering processes, and mathematical reasoning. Based on these qualitative findings, the study proposes a reconstruction model linking local knowledge, chemical concepts, and STEM integration as a basis for contextual chemistry learning. The findings suggest the potential of this reconstruction for informing the development of culturally responsive teaching materials, worksheets, media, and learning designs in diverse Indonesian contexts. However, the proposed Ethno-STEM framework has not yet been validated through classroom implementation. Therefore, its feasibility and effectiveness for supporting students' chemistry learning cannot yet be established from the present study.

RECOMMENDATION

Future research is recommended to implement and test the effectiveness of the local knowledge reconstruction model produced in various high school chemistry learning contexts to evaluate its impact on students' conceptual understanding, scientific literacy, critical thinking skills, and problem-solving abilities. Additionally, this model can be further developed thru the preparation of teaching modules, Student Worksheets (LKPD), learning media, or assessments based on ethnoscience and STEM, and replicated in various local cultural potentials in Indonesia, thereby expanding the application of contextual chemistry learning, supporting the implementation of the Merdeka Curriculum, and contributing to the preservation of local knowledge as part of sustainable science education.

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AUTHOR CONTRIBUTIONS STATEMENT

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Catur Fathonah Djarwo	✓	✓			✓	✓	✓	✓	✓	✓	✓			
Bevo Wahono	✓	✓			✓					✓				
Joko Waluyo	✓	✓			✓	✓		✓		✓	✓			
Indah Slamet Budiarti	✓				✓	✓	✓	✓	✓	✓	✓			

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

ETHICAL APPROVAL

This study involved human participants, including traditional leaders, sago farmers, and community members in Jayapura Regency, Papua, Indonesia. All participants were informed about the purpose of the study and participated voluntarily after providing verbal informed consent. Participants' identities were kept confidential, and the information obtained was used solely for research purposes.

DATA AVAILABILITY

The data supporting the findings of this study are available from the corresponding author upon reasonable request. These data include interview transcripts, observation records, and documentation related to the traditional knowledge and practices of sago (*Metroxylon sp.*) processing in Jayapura Regency, Papua, Indonesia. To protect the privacy and confidentiality of the informants, access to the original interview data may be restricted, and identifying information will not be disclosed.

REFERENCES

Aikenhead, G. S., & Michell, H. (2011). *Bridging Cultures: Indigenous and Scientific Ways of Knowing Nature*. Pearson Canada.

Anor, C. E., Lundell, J., Hanson, R., & Oppong, E. (2022). Students' Engagement in Learning by Indigenous Knowledge-Chemistry Lesson. *LUMAT: International Journal on Math, Science and Technology Education*, *10*(1), 388–414. https://doi.org/10.31129/LUMAT.10.1.1715

Badan Standar dan Asesmen Pendidikan. (2022). *Panduan Pengembangan Projek Penguatan Profil Pelajar Pancasila*. Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi.

Bennett, J., Lubben, F., & Hogarth, S. (2007). Bringing Science to Life: A Synthesis of the Research Evidence on the Effects of Context-Based and STS Approaches to Science Teaching. *Science Education*, *91*(3), 347–370. https://doi.org/10.1002/sce.20186

Broman, K., Bernholt, S., & Parchmann, I. (2015). Analysing Task Design and Students' Responses to Context-Based Problems Through Different Analytical Frameworks. *Research in Science & Technological Education*, *33*(2), 143–161. https://doi.org/10.1080/02635143.2014.989495

Budiarti, I. S., Lumbu, A., Boy, B. Y., & Wabiser, Y. D. (2026). Looking through ethnoscience in rural areas of Jayapura: A perspective study in science learning. *Tadris: Jurnal Keguruan Dan Ilmu Tarbiyah*, *11*(1), 135–145.

Bybee, R. W. (2013). *The Case for STEM Education: Challenges and Opportunities*. NSTA Press.

Chibuye, M., & Singh, P. (2024). Ethnochemistry as a Context for Integrating Indigenous Knowledge into Chemistry Curricula: A Review of Opportunities and Challenges. *Heliyon*, *10*(8), e29174. https://doi.org/10.1016/j.heliyon.2024.e29174

Dewi, C. A., Khery, Y., & Erna, M. (2019). An ethnoscience study in chemistry learning to develop scientific literacy. *Jurnal Pendidikan IPA Indonesia*, *8*(2), 279–287. https://doi.org/10.15294/jpii.v8i2.19261

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing Scientific Knowledge in the Classroom. *Educational Researcher*, *23*(7), 5–12.

Facione, P. A. (1990). *Critical Thinking: A Statement of Expert Consensus for Purposes of Educational Assessment and Instruction (The Delphi Report)*. California Academic Press.

Gilbert, J. K. (2006). On the Nature of "Context" in Chemical Education. *International Journal of Science Education*, *28*(9), 957–976. https://doi.org/10.1080/09500690600702470

Gultom, H., & Rohaeti, E. (2024). The Effectiveness of the Ethnochemistry-Based Problem-Based Learning Model on Students' Problem-Solving Ability in Chemistry Learning: A Meta-Analysis Study in 2021–2024. *Jurnal Penelitian Pendidikan IPA*, *10*(7), 508–514. https://doi.org/10.29303/jppipa.v10i7.8089

Hadinugrahaningsih, T., Rahmawati, Y., & Ridwan, A. (2017). Developing 21st-Century Skills in Chemistry Classrooms: Opportunities and Challenges of STEAM Integration. *AIP Conference Proceedings*, *1868*, 30001. https://doi.org/10.1063/1.4995107

Hakim, A., Jamaluddin, Al Idrus, S. W., & Ramandha, M. E. P. (2020). The use of SASAMBO culture in learning natural product chemistry to support traditional health tourism in Lombok and Sumbawa Islands. *Jurnal Penelitian Pendidikan IPA*, *6*(2), 178–183. https://doi.org/10.29303/jppipa.v6i2.435

Heliawati, L., Lidiawati, L., Adriansyah, P. N. A., & Herlina, E. (2022). Ethnochemistry-based Adobe Flash learning media using indigenous knowledge to improve students' scientific literacy. *Jurnal Pendidikan IPA Indonesia*, *11*(2), 271–281. https://doi.org/10.15294/jpii.v11i2.34859

Hikmawati, H., Suastra, I. W., Suma, K., Sudiatmika, A. I. A. R., & Rohani, R. (2021). The effect of problem-based learning integrated local wisdom on student HOTS and scientific attitude. *Jurnal Penelitian Pendidikan IPA*, *7*(SpecialIssue), 233–239. https://doi.org/10.29303/jppipa.v7iSpecialIssue.1118

Irawati, R. K., Wicaksono, A. T., Salamiyah, S., Sofianto, E. W. N., & Wijaya, T. T. (2023). Exploration and inventory of Banjar ethnochemistry as a learning source in Indonesian senior high school chemistry context. *Jurnal Tadris Kimiya*, *8*(1), 42–58. https://doi.org/10.15575/jtk.v8i1.22380

Johnstone, A. H. (1991). Why is science difficult to learn? Things are seldom what they seem.

Journal of Computer Assisted Learning, *7*(2), 75–83. https://doi.org/10.1111/j.1365-2729.1991.tb00230.x

Kasi, Y. F., Samsudin, A., Widodo, A., & Riandi, R. (2021). A thematic review on exploring ethnoscience in science education: A case in Indonesia. *Tadris: Jurnal Keguruan Dan Ilmu Tarbiyah*, *6*(2), 229–241. https://doi.org/10.24042/tadris.v6i2.9509

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education*, *3*(11), 1–11. https://doi.org/10.1186/s40594-016-0046-z

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Sage Publications.

Mashami, R. A., Suryati, S., Harisanti, B. M., & Khery, Y. (2023). Identification of local wisdom of the Sasak tribe in chemistry learning as an effort to strengthen student character. *Jurnal Penelitian Pendidikan IPA*, *9*(1), 337–345. https://doi.org/10.29303/jppipa.v9i1.2434

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), 79–100. https://doi.org/10.62870/educhemia.v10i2.35755

Miles, M. B., Huberman, A. M., & Saldaña, J. (2014). *Qualitative data analysis: A methods sourcebook* (3rd ed.). Sage Publications.

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), 81–89. https://doi.org/10.62383/pentagon.v2i2.200

OECD. (2023). *PISA 2022 results (Volume I): The state of learning and equity in education*. OECD Publishing. https://doi.org/10.1787/53f23881-en

Parmin, P., Nuangchalerm, P., & El Islami, R. A. Z. (2019). Ethnoscience-based learning and students' scientific literacy. *Journal of Baltic Science Education*, *18*(2), 289–301.

Polya, G. (1957). *How to Solve It: A New Aspect of Mathematical Method* (2nd ed.). Princeton University Press.

Rahmawati, Y., Ridwan, A., Cahyana, U., & Febriana, D. (2020a). The Integration of Culturally Responsive Transformative Teaching to Enhance Student Cultural Identity in the Chemistry Classroom. *Universal Journal of Educational Research*, *8*, 468–476. https://doi.org/10.13189/ujer.2020.080218

Rahmawati, Y., Ridwan, A., Cahyana, U., & Febriana, D. (2020b). The integration of culturally responsive transformative teaching to enhance students' cultural identity in the chemistry classroom. *Universal Journal of Educational Research*, *8*(2), 468–476. https://doi.org/10.13189/ujer.2020.080218

Sanders, M. (2009). STEM, STEM education, STEMmania. *The Technology Teacher*, *68*(4), 20–26.

Sidiq, F. F., Coles, D., Hubbard, C., Clark, B., & Frewer, L. J. (2021). Sago and the indigenous peoples of Papua, Indonesia: A review. *Journal of Agriculture and Applied Biology*, *2*(2), 138–149. https://doi.org/10.11594/jaab.02.02.08

Sidiq, F. F., Coles, D., Hubbard, C., Clark, B., & Frewer, L. J. (2022). Factors influencing consumption of traditional diets: Stakeholder views regarding sago consumption among the indigenous peoples of West Papua. *Agriculture & Food Security*, *11*, 51. https://doi.org/10.1186/s40066-022-00390-5

Snively, G., & Corsiglia, J. (2001a). Discovering indigenous science: Implications for science education. *Science Education*, *85*(1), 6–34. https://doi.org/10.1002/1098-237X

Snively, G., & Corsiglia, J. (2001b). Discovering Indigenous Science: Implications for Science Education. *Science Education*, *85*(1), 6–34. https://doi.org/10.1002/1098-237X

Sumarni, W., Sudarmin, S., Susilogati, S., & Sri, S. (2021). Indigenous knowledge of

Indonesian traditional medicines in science teaching and learning using a science – technology – engineering – mathematics (STEM) approach. In *Cultural Studies of Science Education* (Issue 0123456789). Springer Netherlands. https://doi.org/10.1007/s11422-021-10067-3

Susanto, B., Tosuli, Y. T., Adnan, Cahyadi, Nami, H., Surjosatyo, A., Alandro, D., Nugroho, A. D., Rashyid, M. I., & Muflikhun, M. A. (2024). Characterization of sago tree parts from Sentani, Papua, Indonesia for biomass energy utilization. *Heliyon*, *10*(1), e23993. https://doi.org/10.1016/j.heliyon.2024.e23993

Taber, K. S. (2018). The use of cronbach's alpha when developing and reporting research instruments in science education. *Research in Science Education*, *48*(6), 1273–1296. https://doi.org/10.1007/s11165-016-9602-2

Tako, M., Tamaki, Y., Teruya, T., & Takeda, Y. (2014). The principles of starch gelatinization and retrogradation. *Journal of Applied Glycoscience*, *61*(1), 1–6.

Talanquer, V. (2011). Macro, submicro, and symbolic: The many faces of the chemistry "triplet." *International Journal of Science Education*, *33*(2), 179–195. https://doi.org/10.1080/09500690903386435

UNESCO. (2021). *Reimagining Our Futures Together: A New Social Contract for Education*. UNESCO.

Usman, N., Rahmatan, H., & Haji, A. G. (2019). Ethno-science Based Module Development on Material Substance and Its Characteristics to Improve Learning Achievement of Junior High School Students. *International Journal of Innovation in Science and Mathematics*, *7*(3), 148–157.

Wahono, B., Lin, P.-L., & Chang, C.-Y. (2020). Evidence of STEM enactment effectiveness in Asian student learning outcomes. *International Journal of STEM Education*, *7*, 36. https://doi.org/10.1186/s40594-020-00236-1

Wakhidyah, S. H., Waluyo, J., & Aristya Putra, P. D. (2026). Analisis Validitas Modul IPA Berbasis Etno-STEM Untuk Meningkatkan Kemampuan Berpikir Tingkat Tinggi Siswa. *Cetta: Jurnal Ilmu Pendidikan*, *9*(2), 197–206. https://doi.org/10.37329/cetta.v9i2.5189

Zidny, R., & Eilks, I. (2020). Integrating Perspectives from Indigenous Knowledge and Western Science in Secondary and Higher Chemistry Learning to Contribute to Sustainability Education. *Sustainable Chemistry and Pharmacy*, *16*(June), 1–9. https://doi.org/10.1016/j.scp.2020.100229