

Mapping Papuan Ethnoscience Contexts onto PISA 2025 Scientific Literacy Competencies in the Indonesia–Papua New Guinea Border Region

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Abstrak

The urgency of this study lies in integrating Papuan ethnoscience contexts with PISA 2025 scientific literacy competencies to promote culturally relevant science education in the Indonesia–Papua New Guinea border region. Scientific literacy achievement of Indonesian students remains low, and the gap widens in Papua’s RI–PNG border region where instruction is rarely anchored in students’ lived experience. No inventory yet maps border cultural practices onto the three scientific literacy competencies of the PISA 2025 framework, so materials development risks being generic. This study aims to 1) analyse which cultural contexts are most relevant as science learning scenarios, and 2) map those contexts onto the three competencies, using a qualitative descriptive design. Data were collected through semi-structured interviews with 25 purposively selected informants, namely 5 teachers, 8 parents, 3 community members, and 9 students across four schools in Muara Tami District, complemented by field notes and document review. Every cluster was scored on two separate rubrics, namely empirical evidentiary strength and scientific affordance. Of twelve clusters identified, areca nut and sago–papeda scored highest on both; dance and local language scored highest on evidentiary strength but lowest on affordance; while coconut, tidal dynamics known emically as *meti*, noken, and everyday health knowledge showed useful affordance but weaker community recognition. Empirical support fell sharply across competencies: explaining phenomena was supported by all 25 informants in four schools, constructing enquiry by 7, and decision making by only 3 informants in two schools. Parents were already posing causal questions at home, indicating an untapped household resource. These patterns reveal a systematic disjunction between expressive-ceremonial and resource-based culture, which plausibly explains why ethnoscience integration often halts at the illustrative level. The resulting scored context bank, status-marked matrix, and seven design principles give developers a verified starting point that prioritises the weakest competency.

Keywords: *Science Literacy, Pisa 2025, Ethnoscience, Papuan Culture, Indonesia–Papua New Guinea Border*

Introduction

Science literacy is the ability to use scientific knowledge to understand the world, not merely to memorize concepts. The PISA 2025 science framework defines it as three competencies: 1) explaining phenomena scientifically, 2) designing and evaluating investigations and interpreting evidence, and 3) using scientific information for decision-making and action (OECD, 2023b). This framework requires a learning context that students can truly relate to. However, science literacy levels in Indonesia remain low, indicating a need for competency-based learning (OECD, 2023). The gap is even more pronounced in Papua, particularly in the Indonesia–Papua New Guinea border region and the 3T areas, as the issue

is not only low achievement but also the lack of a learning context that is appropriate to students' culture, language, and life experiences. Science literacy in Papua does indeed still need to be strengthened (Budiarti & Tanta, 2021). And a sociocultural module-based approach emphasizes that a highly contextual design is essential (Simbolon et al., 2025).

Theoretically, this effort is grounded in two traditions. The "funds of knowledge" tradition views practices that develop at home and in the community as legitimate intellectual resources for learning and is now being applied to culturally responsive science education (Hogan & Bae, 2025). The "cultural border crossing" tradition explains that students must cross the boundary between everyday culture and the culture of school science, and the ease or difficulty of that transition determines their success in learning. Both authors emphasize the same point: the issue is not about bringing culture into the classroom, but rather about selecting cultural elements that can truly bridge that gap (Riskawati et al., 2025).

Several studies have shown that the integration of local culture makes learning more concrete and strengthens science literacy (Kelana et al., 2025; Verawati & Wahyudi, 2024; Idris et al., 2026). Recent systematic reviews have confirmed the contribution of ethnoscience to various student competencies (Anori et al., 2026; Sihombing et al., 2025). Derivative products have been developed, ranging from ethnoscience worksheets to validated teaching modules (Nisa' et al., 2024; Supriatna et al., 2025; Sutanto et al., 2026). In the context of Papua, recent research has highlighted traditional games as a medium for teaching physics and chemistry instruction based on the ethnoscience of indigenous communities (Lumbu et al., 2026; Marpaung et al., 2025). While culturally responsive science instruction is considered to have the potential for application in Indonesian science classrooms (Handayani & Triyanto, 2026).

However, this body of research leaves three key gaps. First, in terms of geography, most studies of Papuan ethnoscience are set in urban or mountainous contexts, whereas the Indonesia–Papua New Guinea border region features a coastal-lowland ecology with a diverse population of transmigrants; thus, the cultural context of one region cannot be assumed to apply to another. Second, from a methodological perspective, existing studies generally proceed from the researchers' assumptions to product development without first verifying them with teachers, students, parents, and the community; such verification has only been undertaken in a few mapping studies (Fiskawarni et al., 2025; Hunaepi et al., 2024). Third, conceptually, there is no mapping that links the cultural practices of Papuans in border areas to the three PISA competencies separately; as a result, cultural integration remains limited to an illustrative function and does not extend to the contexts of inquiry or decision-making even though these two areas account for two-thirds of the PISA science literacy construct.

Based on this, the researcher was interested in conducting a study titled "Exploration of PISA-Standardized, Papua-Culture-Based Science Literacy Components in the Indonesia–Papua New Guinea Border Region." The research questions are: 1) What cultural contexts are most relevant to serve as science scenarios for students in the Indonesia–Papua New Guinea border region, and 2) How can the selected contexts be mapped to the three PISA 2025 science literacy competencies?. Its novelty lies in 1) the mapping of factual data on border-area culture to PISA competencies, based on four categories of sources rather than the researchers' assumptions; 2) the separation of cluster assessments into two independent rubrics, thereby revealing discrepancies between them; and 3) the reporting of enabling factors and barriers at the school level that determine the tool's applicability. The results of this study are expected to serve as a valid and authentic baseline for the development of

science literacy-oriented learning materials based on the culture of the Papua region along the Indonesia–Papua New Guinea border.

Method

Research Design and Subject

This study employs a descriptive qualitative approach to explore factual information about the components of science literacy rooted in the culture of the Papuan border region, and this design is appropriate for early-stage research that serves as the foundation for product development in subsequent stages (Kim et al., 2017). The analytical framework was established in advance through a literature review, specifically the three competencies outlined in the PISA 2025 Science Framework (OECD, 2023). The exploration focused on diverse cultural contexts relevant to students' experiences, scientific phenomena that can be derived, potential local evidence that can be observed, and opportunities for decision-making based on scientific information.

The study was conducted at four educational institutions in Muara Tami District and the surrounding area, namely Skouw Mabo Elementary School, Koya Timur State Elementary School 1, Jayapura State Junior High School 10, and Muara Tami Junior High School, which were selected purposefully based on considerations of accessibility in the border region, representation of educational levels, and community diversity. Skouw is a coastal area with a relatively homogeneous Port Numbay community, while Koya is a transmigration area with a diverse ethnic composition.

The subjects were selected through purposive sampling based on the criteria of familiarity with the local culture, teaching expertise, and closeness to the students. There were 25 informants in total, consisting of 5 teachers (T1–T5), 8 parents (P1–P8), 3 community members (CM1–CM3), and 9 students (S1–S9). Students were intentionally made the largest group because the research question required the identification of a context closely related to their experiences; they were selected by the teacher based on their willingness to participate and their representativeness of the class, which could potentially introduce a selection bias toward students who are more communicative. The community members interviewed were well-versed in local cultural practices but were not traditional leaders holding formal positions.

Data Collection

The instrument consists of a semi-structured interview guide in four versions based on informant categories; all versions follow the PISA framework and thus include sections of questions on everyday cultural practices, accompanying natural phenomena, opportunities for observation and evidence collection, and situations requiring decision-making. The teacher's guide includes additional sections on integration experiences, barriers, cultural sensitivity, and the availability of teaching materials.

The interviews were conducted in the Papua Malay variety of Indonesian that the informants use in their daily lives, so that they could describe their experiences using the terms they actually use. The transcription was done verbatim without standardization, as standardization risks removing markers of local knowledge which are, in fact, the very subject of this study; when presenting quotations, the researcher only removed filler words and added explanatory notes in parentheses when the speech might confuse readers from outside the community. All recordings were transcribed twice, and the second round yielded three additional informants as well as a number of local terms that had not been captured

previously. The researchers also compiled reflective field notes and requested that teachers at the four schools provide feedback on the instructional materials.

Data Analysis

The analysis was conducted interactively through data organization, coding, condensation, matrix presentation, and the drawing and verification of conclusions. The thematic procedure followed six steps (Nowell et al., 2017), namely 1) familiarization with the data, 2) inductive open coding, 3) grouping codes into contextual clusters, 4) deductive coding using the three PISA competencies as an a priori framework, 5) cluster scoring across two rubrics, and 6) matrix compilation and reporting. Coding was performed by all three researchers based on an iteratively revised code book, and differences in interpretation were resolved through discussion until consensus was reached (Roberts et al., 2019).

Two scoring categories were established before the scoring took place. The first rubric, strength of empirical evidence, measures the extent to which the existence of a cluster is confirmed in the field; the score is the sum of the number of informants who mentioned the cluster (1–4) plus the number of educational institutions where the cluster appeared (1–4), resulting in a range of 2–8, with “very strong” for 7–8, “strong” for 5–6, “moderate” for 3–4, and “weak” for 2. The second category, scientific potential, measures the number of PISA competencies supported by informants’ accounts, on a scale of 0–3. A competency is considered supported only if there are informant accounts indicating activities or considerations at that level, not merely because the researcher assesses that the cluster could theoretically be developed. The operational criteria are: K1 when the informant mentions a cultural object or practice that can be linked to a scientific concept; K2 when reporting observations, comparisons, or data collection that has been conducted; and K3 when describing a situation that requires consideration or action based on scientific information.

The two categories were separated because they measure different constructs namely, community recognition and productivity in science learning and the discrepancy between the two was, in fact, one of the findings of this study. The mapping matrix is the product of the researchers’ analysis, not the result of verification of implementation; therefore, each item was marked to distinguish those that teachers had implemented from the researchers design propositions. Credibility is maintained through source triangulation, rich descriptions, sufficient references, and an audit trail. The researchers openly state that structured learning observations and formal member checking have not yet been conducted at this stage due to limitations in access and fieldwork time.

Ethical Considerations

The study was conducted after obtaining permission from the Muara Tami District government and the principals of the four schools via Permit Letter No. 10.17/03/IUP/2026 dated April 28, 2026. All informants were briefed on the purpose of the study and gave their verbal consent for their statements to be published. For participants who were all under the age of eighteen, consent was obtained at two levels: permission from the school principal, who was responsible for the students during school hours, and the participants verbal consent, which included the right to stop the interview at any time. Parental consent was not sought separately, and this limitation is noted in the Conclusion section.

Anonymization was a direct request from informants who were willing to have their statements published as long as their real names were not disclosed, and the researcher complied by using category codes because codes provide stronger protection than initials in

small communities. Practices identified as restricted or sacred were not included. Audio-to-text transcription was assisted by artificial intelligence and limited to that stage; the entire output was cross-checked against the original recording, while coding, interpretation, and writing were performed by the researchers.

Result

Cultural Context Clusters and Their Scores

Open coding of the 25 transcripts yielded twelve cultural context clusters with scores as shown in Table 1.

Table 1. Scores for the strength of empirical evidence and scientific potential of the twelve cultural context clusters

cluster	Source category	Educational institutions	Evidence score	Label	Scientific potential
A. Areca Nut	4	4	8	very strong	3
B. Sago and papeda	4	4	8	very strong	3
C. Dances, tifa drums, and traditional festivals	4	4	8	very strong	1
D. local language	4	3	7	very strong	1
E. coconut	3	3	6	strong	2
F. Coast and Meti	3	3	6	strong	2
G. Noken and woven items	3	3	6	strong	2
H. Health and Food Taboos	2	3	5	strong	2
I. Bird of paradise feather crown	2	2	4	Currently	2
J. Farms and Cropping Cycles	2	2	4	Currently	2
K. Mangroves and Coastal Erosion	1	1	2	weak	1
L. The Tami River and Estuary	1	1	2	weak	1

Concrete examples include betel nuts in the schoolyard, along with their drying and sale; the processing of sago into papeda; the Yospan, Tambur, Lok, and cawat dances, along with the Gantung Tambur celebration; the Port Numbay and Skouw languages, with terms such as meti, men, and gesek sagu; copra, pure coconut oil, and the 1,000 Coconuts Festival; seasonal tidal patterns and coastal wildlife; noken weavings and palm-leaf plates; the plumage of the bird-of-paradise; the planting cycles of taro, cassava, and pineapple; dietary taboos and susceptibility to malaria; mangrove stands; and the Tami River estuary, along with traditional stories about the demarcation of river boundaries.

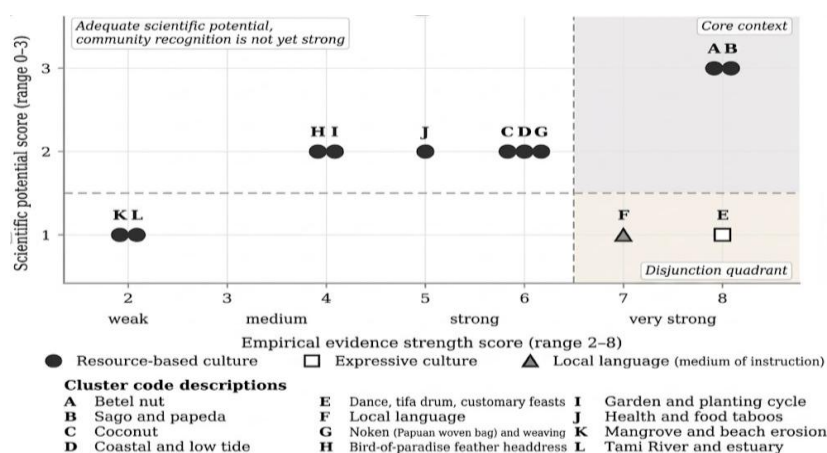


Figure 1. Distribution of the twelve cultural context clusters across the two assessment rubrics. The positions are shifted slightly horizontally when multiple clusters receive the same score.

Four clusters received the highest evidence scores: areca nut (8), sago and papeda (8), traditional dances and festivals (8), and local languages (7). However, only two of these also received the highest scientific potential scores: areca nut (3) and sago and papeda (3). Traditional dances and local languages received the lowest scientific potential scores, along with mangroves and the Tami estuary, at 1. The distribution of both scores is presented in Figure 1.

Figure 1 shows three clusters: betel nut, sago, and papeda in the high-evidence, high potential quadrant; traditional dances, cultural festivals, and local languages in the high-evidence, low potential quadrant; and coconut, coastal areas, noken, health knowledge, bird of paradise feather crowns, and gardens in the moderate to strong evidence range with medium potential. The remaining two clusters scored low on both axes.

The criterion of ecological proximity consistently emerged as the basis for informants' references to a particular context, and in the coastal cluster, a teacher used a local term in place of the curriculum term.

"The reason is that this is the most common plant around here in the village. At this school." (G1)

"We usually use the term low tide. But here, it's not called low tide it's called meti. So we learn to look for animals when the water has gone out, or meti." (G1)

"With this sago, let's say we're making papeda. We wash the sago with water, then add lime juice, and after that we boil some water. Then we slowly pour the hot water in while stirring." (OT2)

A parent believes that education in local wisdom is both important and rare in schools.

"It's very important. It's just rare in schools these days." (OT1)

Practicing Cause-and-Effect Questions at Home

A number of parents reported the habit of asking their children cause-and-effect questions, including about abstract concepts. A parent at Skouw Mabo Elementary School explained the Earth's rotation to their child, and another parent sparked their child's curiosity as follows.

"For example, questions such as 'Why does this water exist, and is it possible for water to turn into stone?' are essentially stimuli we provide to participants to stimulate their critical thinking skills." (OT8)

Similar practices included comparing boiled and unboiled water in relation to sugar solubility, as well as differences in the growth periods of taro, pineapple, and cassava. Since these practices were not grouped into a single cluster, they were not included in Table 2.

Empirical Support for Each Competency

The application of the operational criteria resulted in the distribution shown in Table 2 below.

Table 2. *Empirical support from informants' accounts for each PISA 2025 science literacy competency*

competency	support cluster (of 12)	informants who contributed out (of 25)	Educational institutions (of 4)
K1 Explain phenomena scientifically	12	25	4
K2 Designing an investigation and	5	7	4

competency	support cluster (of 12)	informants who contributed out (of 25)	Educational institutions (of 4)
interpreting evidence K3 Using Scientific Information to Make Decisions	5	3	2

Support for K1 covered all clusters and all informants at the four schools. Support for K2 came from five clusters betel nut, sago and papeda, coconut, coastal, and garden with seven informants at the four schools. Support for occupational safety and health also came from five clusters: betel nut, sago and papeda, noken, the bird of paradise feather crown, and health knowledge; however, these were mentioned by only three informants from two schools, and only three of them involved explicit value conflicts: noken, the bird-of-paradise feather crown, and health knowledge.

Most of the other K3 candidates referred to routine household decisions, such as choosing school supplies and setting limits on cell phone use, and therefore did not meet the criteria because they did not involve scientific information as the basis for their decisions.

Context to Competency Mapping Matrix

The results of the deductive coding for all clusters are presented in Table 3 below.

Table 3. Mapping Matrix of the Twelve Cultural Context Clusters to the Three PISA 2025 Science Literacy Competencies

Cluster (Level)	K1 Explain the phenomenon	K2 Investigation and Evidence	K3 Decisions and Actions
A. Pinang (Elementary School, Middle School)	Biotic and abiotic factors in home gardens; oxidation of phenolic compounds by lime	The Effect of Lime Content on Color; Harvest Data and Weekly Prices*	The Economics of Health; Regulations on the Management of Food Waste*
B. Sago and papeda (Elementary and Middle School)	Starch gelatinization; the effect of temperature on viscosity*	Temperature variations and material comparisons; the effect of adding acid	Evidence-based nutritional decisions; the decline of sago villages
C. Coconut (Middle School)	Coconut milk emulsion; evaporation of copra and salt; heat transfer*	Seven-day observation of pure coconut oil*; consumption data analysis*	Added value of copra compared to pure oil; food safety
D. Coastal Areas and Meti (Elementary and Middle School)	Tides; onshore and offshore winds; biotic zoning*	Meti schedule based on the lunar phases; biota transects	Safe times for fishing; conservation of coastal resources
E. Dance, tifa, traditional celebrations (elementary and middle school)	Vibrations and sound waves; muscle work and energy*	The tension of the tifa membrane at a given pitch; pulse	Benefits of physical activity; traditional participation and school attendance
F. Local Language (Elementary School, Middle School)	Local naming of phenomena as a bridge to curriculum terminology*	Unidentified	Unidentified
G. Noken and Woven Crafts (Elementary and Middle School)	Properties of natural fibers; sustainability of the material	Tensile strength and load-bearing capacity of noken against plastic	Replacing plastic bags; a campaign in schools*
H. Crown of the Bird of	Biodiversity; protected	Evaluation of population	Traditional values

Cluster (Level)	K1 Explain the phenomenon	K2 Investigation and Evidence	K3 Decisions and Actions
Paradise (Middle School)	species	status claims; evidence supporting the opinion	regarding conservation; alternative materials
I. Farms and crop rotation (Elementary School)	Vegetative reproduction; the life cycle of plants	Comparison of growth rates among species	Farming Practices and Household Food Security
J. Kesehatan dan tabu makanan (Middle School)	Allergic reactions; malaria transmission; sago worm nutrition	Correlation versus causation in traditional claims	Malaria prevention: reasoning without breaking taboos
K. Mangroves and Coastal Erosion (Elementary and Middle School)	The Role of Roots in Sedimentation and Erosion	Coastlines with vegetation versus those without	Mangrove Rehabilitation Stand
L. The Tami River and Estuary (Elementary School, Middle School)	Where freshwater meets the sea; estuarine sedimentation	Salinity of water from the headwaters to the mouth	Preserving river water quality for downstream residents

*Note: Items marked with an * have been implemented by a teacher informant; unmarked items are the researcher's design propositions that have not yet been tested.*

Device Availability and Integration Practices in Schools

A review of the documents revealed not a single teaching module, worksheet, or learning resource incorporating Papuan culture in any of the schools visited. The only materials that had ever existed worksheets on making pure coconut oil and coconut milk ice cream created by G5 could not be presented because they had not been archived after the student moved up a grade level.

The current integration practices are on a personal basis and limited to two teachers. G5 reported on assignments involving the production of salt from seawater, coconut milk ice cream, and pure coconut oil, with daily records kept for one week, as well as the collection of data on coconut consumption during the harvest festival, which was then calculated as an average. G4 reported on the calculation of weekly areca nut sales, price negotiation simulations, the calculation of climbers' wages, and the campaign to replace plastic bags with noken. The other three teachers are still limited to introducing local terms and greetings. A new approach was identified at Koya Timur Public Elementary School No. 1: the inclusion of mashed taro in the Free Nutritious Meals program, which teachers linked to lessons on food and digestion.

Three barriers were identified. First, the teachers' limited cultural knowledge; G3 was unaware of the origins or how to make a noken, even though her students used it daily, and field notes documented the teacher's difficulty in explaining the color change in the mixture of betel nut and lime. Second, the risk of misunderstandings within the community, such as the case where some parents misinterpreted the use of driftwood models of human organs. Third, student absences due to helping their parents in the fields, participating in traditional ceremonies, light rain, lack of transportation, and false rumors about school holidays along with the fact that some students at both grade levels are not yet fluent readers. In addition, some informants simply remained silent or nodded in response to certain sets of questions

particularly those regarding cause and effect relationships, general local knowledge, and requests for advice while questions referring to specific objects were almost always answered.

Discussion

Convergence in Resource Based Culture

The two clusters with the highest scores in both rubrics betel nut, and sago and papeda are both examples of daily resource management practices. This finding is consistent with previous mapping studies that found that the greatest scientific potential lies precisely in everyday practices, rather than in the most prominent cultural symbols (Fiskawarni et al., 2025; Hunaepi et al., 2024). The convergence across the four source categories in the areca nut cluster reinforces this conclusion while also providing an empirical basis for the research team's previous study (Kelana et al., 2025); the difference is that areca nut has now been confirmed across teachers, students, parents, and community members, rather than being selected based on the researchers own judgment.

The sago and papeda cluster is particularly valuable because the accounts provided by non-teacher informants already include all the variables under investigation: water temperature, the order in which ingredients are added, stirring speed, and the addition of acid. Within the framework of "funds of knowledge," such accounts represent household intellectual resources that are ready to be transferred to the classroom without simplification. The practice of asking cause and effect questions at home reinforces this argument even further: parents not only provide cultural objects but also engage in a pattern of questioning that resembles scientific inquiry, even regarding phenomena as abstract as the Earth's rotation and the changes in the state of water. What is still missing is an institutional bridge that connects the pattern of questioning at home with that in the classroom. The term "meti" indicates that the path toward a school culture of science is not merely a path of objects, but also a path of language; once a phenomenon has been named in the community's language, students need only link the familiar name to its scientific explanation (Handayani & Triyanto, 2026).

The Disjunction Between Expressive Culture and Resource Based Culture

The most striking finding from Figure 1 is the quadrant occupied by two clusters with the highest evidence scores but the lowest scientific potential: traditional dances and festivals, and local languages. The researchers termed this group "expressive culture" that is, identity marking practices that take place ceremonially and periodically with very high symbolic visibility. The counterpart is a resource based culture that is, everyday environmental management practices that have low symbolic visibility but provide observable and measurable objects, processes, and variables.

P This conclusion is supported by three sources of evidence. First, Figure 1 shows that two expressive clusters are distinct from the other ten clusters on the scientific potential axis. Second, when asked to name the most prominent aspects of Papuan culture, the informants answers were almost uniformly dance and language; however, when asked to name the aspects that children could most easily observe or that were most likely to be used as material for science lessons, their answers shifted to betel nuts, coconuts, sago, gardens, and the ocean. Third, explicit evidence came from the teacher with the longest tenure teaching science.

"Integrating culture into the learning system is a rather complex challenge. In contrast, integrating resources into learning is actually quite easy" (G5)

This statement aligns with the admission of another teacher who was unaware of the origins of the noken even though their students use it every day, while the same teacher readily cited betel nut and sago as examples in their teaching. The fourth piece of evidence comes from the opposite perspective: a resident in the neighborhood of SMP Negeri 10 Jayapura stated that there are no traditional practices still strongly observed in their community, whereas another resident at the same school mentioned the welcome dance and Yospan. These differences within a single school community underscore that expressive culture not only lacks scientific rigor but is also unevenly distributed across transmigration areas. Familiarity with cultural objects, therefore, does not correlate directly with the ability to translate them into a scientific context.

This disjunction has three implications. First, the failure of cultural integration does not always stem from a lack of teacher competence, but rather, in part, from a mismatch between the chosen cultural form and the competencies to be developed. Second, expressive culture is not closed off to science but requires a more extensive mediation process; G5 connects the loudspeakers at a traditional festival to vibrations and waves, and dancing to muscle work and energy changes. In both examples, the subject of science is not dance itself, but rather the physical phenomena associated with it; thus, teaching these concepts requires a mastery of concepts that cannot be assumed to be possessed by all teachers. Third, the development of teaching materials should be centered on a resource based culture, with expressive culture serving as the contextual framework; this approach is not a judgment on cultural value but rather a consideration of functional appropriateness.

Figure 1 also shows a third group six clusters with moderate potential and lower evidence scores that are scientifically productive but have not yet gained strong recognition within the community, and therefore require the most effort to raise awareness among residents. These findings complement previous studies, which generally reported the success of ethnoscience integration without distinguishing between the types of cultures being integrated (Nisa' et al., 2024; Sutanto et al., 2026; Verawati & Wahyudi, 2024). The categorization proposed here may explain why some efforts increase science literacy while others merely increase affective engagement.

Disparities in Support Across Competencies

Table 2 shows a sharp decline in empirical support from K1 to K3 from 25 informants across four schools to seven, and then to three informants across two schools. The abundance of K1 examples is easily explained because nearly every cultural object can be linked to a scientific concept, so the illustrative function is fulfilled automatically; indeed, it is precisely this ease that poses a problem, as cultural integration then stops at the level of illustration. A similar trend is evident in systematic reviews, which show that most ethnoscience learning materials are still focused on reinforcing concepts and process skills, while the decision-making dimension is rarely an explicit target (Anori et al., 2026; Sihombing et al., 2025).

Support for K2 was evenly distributed across the four schools, but it came from only seven informants and was largely driven by the initiatives of two teachers. Interestingly, G5 did not view the collection and analysis of coconut consumption data as a science learning activity, even though the activity was intended to train students in data analysis. This assessment highlights the gap between existing best practices and the conceptual framework for recognizing them as science literacy, even though, within the PISA 2025 framework, collecting primary data, calculating measures of central tendency, and drawing conclusions

from local data are at the core of Competency K2 (OECD, 2023b). These findings reinforce previous research indicating that science teachers often already integrate local knowledge but lack a framework for incorporating it into the curriculum (Hogan & Bae, 2025; Mkhwebane, 2024).

The scarcity of support for occupational safety and health (OSH) has the most serious implications and requires the greatest caution in interpretation. Only three clusters contain explicit value tensions: the replacement of plastic bags with noken, the conservation of birds of paradise, and malaria prevention; all three exhibit essential characteristics of socioscientific issues, namely authentic value tensions and demands for informal reasoning (Dauer et al., 2025; Ladachart & Ladachart, 2021). The context surrounding the bird of paradise feather crown even highlights a culturally specific tension between traditional values and conservation obligations, it is precisely this kind of context that is most effective for developing decision-making skills.

Nevertheless, the scarcity of K3 cannot be directly interpreted as a characteristic of the local cultural context, as there are two equally plausible alternative explanations. The first explanation is instrumental in nature and is now supported by direct evidence: The transcripts from the second round show that some informants did not provide verbal responses and simply remained silent or nodded; these instances of non-response were concentrated on questions regarding cause and effect relationships, general local knowledge, and requests for advice, whereas questions referring to concrete objects were almost always answered. This pattern is consistent with research indicating that cultural context helps determine what is considered appropriate to discuss in an interview; therefore, an informant's silence should not be interpreted as a lack of knowledge (Bayeck, 2021). The second explanation is situational: decision-making based on scientific information generally arises when there is a concrete trigger, so individual interviews without dilemma scenarios are unlikely to elicit it. Consequently, exploring OSH requires different techniques, such as focused group discussions using dilemma scenarios; and until such techniques are employed, the only tenable claim is that support for OSH is scarce in this dataset, not that the OSH context is scarce in this region.

Implications for Tool Development

Based on the overall findings, the researchers formulated seven preliminary design principles. First, the framework centers on clusters that scored high on both rubrics namely, betel nut, sago, and papeda with expressive culture serving as an introductory framework rather than the source of the phenomenon. Second, the units are designed in reverse from the K3 approach that is, starting from the formulation of decision making tasks and then moving backward to investigation and conceptualization, with three clusters of conflicting values as the starting point. Third, local language registers are intentionally used alongside a bilingual glossary, because the language clusters have very strong evidence scores but low scientific potential, so their function is medium rather than contextual. Fourth, the tool prioritizes local data that students can collect, such as meti schedules, weekly areca nut prices, and coconut consumption during harvest celebrations. Fifth, units that address the body, health, or traditional practices include information sheets for parents and a mechanism for consulting with local leaders. Sixth, the program is designed to be modular and short term so that it remains meaningful even if students do not attend consecutively. Seventh, the Free Nutritious Meals program serves as a gateway to local food contexts, as it has already brought mashed taro into the classroom without any additional effort on the part of teachers and provides an

institutional channel that is rarely available to other contextual initiatives (Nurmansyah & Fitriani, 2025).

The ethnic diversity in the Koya region which is home to residents from Nduga, Lanny Jaya, Serui, Sorong, Oksibil, Pegunungan Bintang, and Merauke requires special care, as the selection of specific ethnic symbols has the potential to exclude some students; therefore, a shared ecological context is a safer approach.

Conclusion

This study identified twelve cultural context clusters in the Indonesia-Papua New Guinea border region and evaluated them using two independent rubrics. Four clusters received the highest evidence strength scores: areca nut, sago and papeda; traditional dances and ceremonies; and local languages. However, only areca nut and sago and papeda also received the highest scientific potential scores and were therefore designated as core contexts. Mapping to the three PISA 2025 competencies revealed a sharp decline in empirical support: from 25 informants across four schools for the competency of explaining phenomena, to seven informants for designing investigations, and only three informants across two schools for decision making. This study also found a systematic disconnect between expressive culture and resource-based culture, which explains why cultural integration often stops at an illustrative function; documented the absence of locally based learning materials in schools; noted that parents already practice cause-and-effect questioning at home; and demonstrated that the Free Nutritious Meals program has brought local foods into the classroom without any additional effort on the part of teachers. This resulted in a baseline consisting of a scored context bank, a status-tagged mapping matrix, and seven preliminary design principles that were previously unavailable for the Indonesia–Papua New Guinea border region.

The findings imply the need for culturally responsive science education while caution is warranted in generalizing the results due to reliance on interviews, limited informant representation, unvalidated design propositions, potential selection bias, and incomplete parental consent. Future research should triangulate findings through classroom observations and teacher focus groups, validate the mapping with science education experts and traditional leaders, explore decision-making competencies through dilemma-based group discussions, and develop and test learning-unit prototypes, while applying a comprehensive consent process for child participants.

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