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How Science Teachers Translate Indigenous Knowledge into Classroom Science: A Qualitative Study in Lombok, Indonesia

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Abstract

This study investigated how science teachers in Lombok, Indonesia, translate Indigenous knowledge from community contexts into classroom science. A qualitative multiple-case design involved 15 science teachers from West, Central, and East Lombok. Data were generated through semi-structured interviews, 26 instructional documents, classroom observations of seven selected teachers, and researcher field memos. Iterative coding, within-case analysis, cross-case comparison, and triangulation were used to analyze the data. The findings revealed six interconnected translation processes: accessing, selecting, interpreting, negotiating, transforming, and representing Indigenous knowledge. Three epistemic positions emerged: contextual bridging, epistemic restraint, and scientific privileging. Pedagogical translation varied from deep to limited or illustrative forms, with one discrepant case. Importantly, epistemic positioning and pedagogical depth were related but distinct dimensions of teacher practice. Classroom enactment generally progressed from familiar local experiences to inquiry or analysis, scientific interpretation, and epistemic comparison. These findings conceptualize Indigenous knowledge integration as a recursive, teacher-mediated translation process and provide an empirical framework for examining culturally responsive and epistemically attentive science teaching.

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INTRODUCTION

Science education does not operate in a culturally neutral space. Students and teachers enter science classrooms with experiences, explanatory traditions, values, language, and ways of understanding the natural world that have developed through family and community life. From an anthropological perspective, learning science can therefore involve movement between different cultural worlds rather than simply acquiring a body of decontextualized concepts (Maddock, 1981; Aikenhead, 1996). This perspective has been particularly influential in research involving Indigenous and local communities, where school science may encounter knowledge systems developed through long-term observation, practice, interaction with particular environments, and intergenerational transmission. Indigenous knowledge should consequently not be treated merely as a collection of cultural examples that can be attached to conventional science lessons. It may embody distinctive relationships among knowledge, practice, place, community, values, and ways of knowing nature (Snively & Corsiglia, 2001; Barnhardt & Kawagley, 2005; Berkes, 2018).

Recognition of this epistemic and cultural diversity has contributed to growing interest in bringing Indigenous knowledge into formal science education. Earlier work on cross-cultural science education emphasized that learners may experience school science as another cultural world and may need to negotiate boundaries between community-based understandings and the norms of scientific knowledge taught in school (Costa, 1995; Jegede, 1995; Aikenhead & Jegede, 1999). Related perspectives have challenged deficit-oriented assumptions that students' everyday or community knowledge necessarily constitutes an obstacle to scientific understanding. Instead, culturally grounded knowledge and everyday sense-making can provide intellectual resources for scientific reasoning when they are meaningfully engaged in classroom activity (Moll et al., 1992; Warren et al., 2001; Barton & Tan, 2009). Culturally relevant and culturally responsive pedagogies similarly emphasize that students' cultural experiences should influence not only the examples presented in lessons but also how knowledge, participation, identity, and learning are organized within educational practice (Ladson-Billings, 1995; Aronson & Laughter, 2016; Smith et al., 2022).

The relationship between Indigenous knowledge and scientific knowledge, however, is more complicated than the language of "integration" sometimes suggests. Indigenous knowledge and school science cannot automatically be assumed to represent either completely separate or fully commensurable systems. Critiques of a rigid Indigenous-scientific knowledge dichotomy have shown that boundaries between knowledge systems may be historically and socially constructed, while important epistemological differences may nevertheless remain (Agrawal, 1995). A multiscience perspective similarly questions the assumption that there is only one legitimate form of systematic knowledge about the natural world (Ogawa, 1995). At the same time, recognizing epistemic plurality does not require treating all knowledge claims as identical in purpose, method, validation, or meaning. Indigenous and scientific ways of knowing may intersect, complement one another, remain distinct, or become contested depending on the phenomenon and context involved (Mazzocchi, 2006; Aikenhead & Michell, 2011). Consequently, meaningful engagement between them requires more than replacing a local explanation with a scientific one or simply demonstrating that a traditional practice contains a modern scientific concept.

This issue becomes particularly important when Indigenous knowledge enters the science classroom. The classroom can be understood as a cultural and epistemic interface in which different traditions of knowledge meet under unequal historical and institutional conditions (Nakata, 2007). Within such an interface, the question is not simply whether Indigenous knowledge is included but how it is positioned. It may be presented as background information, a cultural curiosity, empirical evidence, a problem for investigation, an alternative explanation, a source of scientific concepts, or a knowledge tradition whose meaning cannot be exhausted by school-science interpretation. Bang and Medin (2010) describe science education as involving the navigation of multiple epistemologies, while Andreotti et al. (2011) caution that epistemological pluralism creates ethical and pedagogical challenges when one system of knowledge is interpreted exclusively through the standards of another. These arguments suggest that the educational value of Indigenous knowledge depends considerably on the decisions made when knowledge crosses from community contexts into formal schooling.

Science teachers occupy a central position in this process. They determine which local practices are considered relevant, how those practices are connected with curriculum content, what scientific concepts are used to interpret them, which sources are considered credible, and how disagreements between community explanations and school science are communicated to students. Teachers must also decide what cultural detail should be preserved, simplified, questioned, or excluded when knowledge is transformed into lessons, experiments, discussions, tasks, and assessments. These decisions are simultaneously epistemic and pedagogical. Research has already demonstrated that teachers may adopt different stances toward Indigenous knowledge. Ogunniyi (2007a, 2007b), for example, showed that teachers' beliefs and practical arguments influence how they negotiate science-Indigenous knowledge curricula. Naidoo and Vithal (2014) identified incorporationist, separatist, and integrationist approaches to introducing Indigenous knowledge into school science, demonstrating that teachers do not necessarily position the relationship between knowledge systems in the same way. Studies of culturally responsive science teaching similarly indicate that teachers require specific knowledge, dispositions, and pedagogical capabilities to transform cultural resources into meaningful classroom experiences (Brown & Crippen, 2016, 2017).

Recent research further indicates that integrating Indigenous knowledge into science teaching involves multiple pedagogical possibilities as well as substantial challenges. Classroom studies have documented strategies involving dialogue, community resources, comparison of knowledge systems, practical activities, culturally contextualized materials, and inquiry-oriented learning (Lee et al., 2012; Seehawer, 2018). A recent systematic review found that pedagogical practices for Indigenous knowledge integration include argumentative dialogue, experiential learning, culturally contextualized instructional resources, and engagement with community knowledge holders (Ogegbo & Ramnarain, 2024). Other recent studies have highlighted difficulties related to teachers' knowledge, instructional resources, curriculum demands, practical implementation, and sensitivity toward the cultural meanings attached to Indigenous knowledge (Mkhwebane, 2024; Mlotshwa & Tsakeni, 2024). A broader systematic review of local and Indigenous knowledge in science learning likewise shows expanding international interest in using culturally grounded knowledge within science education (Latip et al., 2024). These studies establish the importance of teacher practice, but they also raise a more detailed question: what actually happens between encountering Indigenous knowledge in a community context and representing it as science learning in the classroom?

This question requires attention because pedagogical use always involves transformation. Teachers rarely transfer knowledge unchanged from one context into another. They select particular elements, reorganize explanations, construct representations, formulate questions, and design activities appropriate to learners and curriculum purposes. In conventional discussions of teacher knowledge, this transformation is a fundamental part of pedagogical reasoning (Shulman, 1986, 1987). When Indigenous knowledge is involved, however, transformation carries an additional epistemic responsibility. Reframing a local practice as an investigation can create opportunities for scientific inquiry, but it can also remove historical, linguistic, ecological, spiritual, or communal meanings that make the practice intelligible within its original context. Indigenous knowledge may consequently become culturally visible while remaining epistemically marginalized if it is used merely as an engaging introduction to a lesson whose authoritative explanation is predetermined by school science. A meaningful analysis must therefore distinguish between the presence of cultural content and the deeper processes through which teachers interpret, negotiate, and pedagogically reconstruct that content.

The Indonesian science education context makes this distinction particularly relevant. Local wisdom and ethnoscience have become visible strands within Indonesian science education research, with studies exploring culturally responsive chemistry teaching, local-wisdom-based biology instruction, ethnoscience-oriented inquiry, and relationships between curriculum reform and local knowledge (Rahmawati, Baeti, et al., 2019; Ramdiah et al., 2020; Suprapto et al., 2021; Verawati et al., 2022). Research involving Sasak culture has similarly demonstrated the potential of local knowledge as a resource for chemistry and science learning (Wahyudiati, 2022; Wahyudiati & Qurniati, 2023). Such studies are important because they establish that culturally embedded practices in Lombok can provide meaningful contexts for scientific learning. However, much of this literature has concentrated on identifying local knowledge as learning content, developing ethnoscience-based materials or models, implementing particular instructional interventions, or examining student learning outcomes.

What remains less visible is the teacher reasoning that precedes and accompanies these pedagogical products. The presence of Sasak knowledge in a worksheet, lesson plan, or classroom example does not reveal how a teacher decided that the knowledge was appropriate for science teaching, how its scientific interpretation was established, how cultural and scientific explanations were compared, or which elements were altered during pedagogical reconstruction. Similarly, evidence that ethnoscience-based instruction improves an educational outcome does not explain how teachers manage moments in which scientific and community accounts are not fully aligned. Examining these processes requires treating the teacher not simply as an implementer of culturally responsive materials but as an active mediator working across knowledge systems. This shifts the analytical focus from whether Indigenous knowledge is integrated to how it becomes classroom science.

Study Novelty

The first novelty of this study lies in conceptualizing the movement of Indigenous knowledge into science classrooms as a process of translation rather than simple integration. Integration often describes the presence or combination of two forms of knowledge but may obscure the decisions through which knowledge changes as it moves between contexts. Drawing conceptually on cultural border crossing, epistemological plurality, and knowledge-system interfaces (Aikenhead, 1996; Nakata, 2007; Bang & Medin, 2010), this study examines translation as a sequence of teacher-mediated decisions involving the recognition and selection of Indigenous knowledge, interpretation in relation to scientific concepts, negotiation of epistemic differences, pedagogical transformation, and classroom representation. The term *translation* does not imply direct equivalence between knowledge systems. Rather, it directs analytical attention to what teachers preserve, reinterpret, compare, transform, privilege, or leave epistemically distinct when they make Indigenous knowledge teachable within school science.

The second novelty is empirical and methodological. Rather than studying a predetermined ethnoscience intervention or evaluating the effectiveness of a particular local-wisdom-based learning model, the study investigates teachers' naturally occurring practices across multiple cases. A qualitative multiple-case approach makes it possible to examine both common processes and meaningful variation among teachers. Importantly, teacher accounts are not treated as the only evidence of practice. Semi-structured interviews are examined alongside instructional documents and selected classroom observations, enabling comparison between what teachers say they do, what is represented in their teaching materials, and what can be observed in classroom enactment. This design provides a stronger basis for identifying convergence, contradiction, and case-specific variation than studies relying solely on perceptions or self-reported attitudes toward Indigenous knowledge.

The third novelty concerns the study's intended theoretical contribution. Previous research has demonstrated that teachers can hold different orientations toward relations between Indigenous and scientific knowledge (Ogunniyi, 2007a; Naidoo & Vithal, 2014) and that respectful knowledge-system engagement requires approaches that avoid reducing one knowledge tradition to the validation criteria of another (Andreotti et al., 2011; Bartlett et al., 2012; Tengö et al., 2014). Building on these concerns, the present study seeks to generate an empirically grounded account of how such epistemic positions become connected to pedagogical decisions in everyday science teaching. The analysis therefore moves beyond identifying strategies of Indigenous knowledge integration toward examining patterns of translation across cases, including differences in epistemic positioning and in the depth with which cultural knowledge is transformed into inquiry, explanation, interaction, and other forms of classroom science. This perspective may provide a process-oriented framework for understanding the teacher's role as both a pedagogical and epistemic mediator.

Research Objectives and Questions

This study aims to investigate how science teachers in Lombok translate Indigenous knowledge from community and cultural contexts into classroom science. Specifically, it seeks to understand how teachers identify and select locally grounded knowledge for instructional use, interpret its relationship with scientific knowledge, negotiate areas of convergence or difference between knowledge systems, transform selected knowledge into pedagogical forms, and represent these relationships during science teaching. Through within-case and cross-case analysis, the study also aims to develop an empirically grounded explanation of the translation process and the variations that occur across teachers. Accordingly, the study addresses the following research questions:

1. How do science teachers identify, select, and interpret Indigenous knowledge for use in classroom science?
2. How do science teachers negotiate epistemic relationships and differences between Indigenous knowledge and scientific knowledge?
3. How do science teachers pedagogically transform and represent Indigenous knowledge in classroom science?

By addressing these questions, the study positions Indigenous knowledge integration not as a singular instructional technique but as a complex process of cultural, epistemic, and pedagogical decision-making. Such a perspective is expected to provide a more precise account of what teachers actually do when culturally grounded knowledge moves from community contexts into formal science education and to clarify the conditions under which this movement preserves, reframes, or constrains the epistemic and cultural meanings carried by that knowledge.

METHODS

Research Design

This study employed a qualitative multiple-case study design to investigate how science teachers translate Indigenous knowledge into classroom science. A multiple-case design was appropriate because the phenomenon under investigation involved teacher reasoning and practice situated within particular educational, cultural, and disciplinary contexts. Rather than treating Indigenous knowledge integration as a single instructional strategy, the study examined how individual teachers encountered local knowledge, determined its relevance for science teaching, interpreted its relationship with scientific knowledge, negotiated epistemic differences, transformed it pedagogically, and represented it during classroom interaction. A multiple-case approach enables close examination of each bounded case while also allowing systematic comparison of recurrent patterns, variations, and contrasting configurations across cases (Stake, 2006; Yin, 2018).

Each participating teacher constituted an individual case. The case boundary encompassed the teacher's professional engagement with Indigenous or locally grounded knowledge in science instruction, including the cultural context involved, its relationship with scientific concepts, the epistemic decisions made by the teacher, and its pedagogical representation. The 15 participating teachers were therefore not treated as a homogeneous group whose responses could simply be aggregated. Each case was first examined within its own context before comparison across cases.

The qualitative orientation was particularly important because the study focused on processes, reasoning, decisions, tensions, and meanings rather than on measuring the frequency or effectiveness of Indigenous knowledge integration. The research instruments were therefore designed to elicit concrete experiences rather than general attitudes toward local wisdom. Teachers were encouraged to describe actual instances of classroom use, explain the reasoning behind their decisions, identify how local and scientific explanations were related, and reflect on how selected knowledge was transformed for teaching. The initial research foci guided data collection as sensitizing concepts, while coding categories, higher-order themes, and cross-case relationships were progressively developed through iterative engagement with the empirical evidence.

Research Context and Participants

The study was conducted in Lombok, Indonesia, during 2026 and involved teachers from West Lombok, Central Lombok, and East Lombok. Lombok provided an appropriate context for examining Indigenous knowledge in science education because locally grounded knowledge remains visible in community practices involving traditional architecture, pottery, food processing, weaving, natural dyes, plants, agriculture, water management, indicators of weather and seasonal change, traditional tools, and coastal environments. These practices were not predetermined by the researchers as scientifically valid or invalid. Instead, the study examined how teachers themselves encountered, selected, interpreted, and pedagogically represented such knowledge.

Participants were selected purposively based on their relevance to the phenomenon under investigation, particularly their experience of using local, cultural, or community-based knowledge in science instruction. Fifteen teachers participated, with five cases representing each of the three study regions. Participant identities were protected through anonymous case codes ranging from T01 to T15. These identifiers were used consistently in interview records, document analysis, classroom observation, case summaries, and cross-case comparison. Table 1 presents the principal characteristics of the cases.

Table 1. Participant and Case Characteristics

Case	Region	School Level	Subject	Teaching Experience	Education	Indigenous/Local Knowledge Context
T01	West Lombok	Junior secondary	Integrated Science	12 years	Master's	Traditional Sasak architecture and local materials

Case	Region	School Level	Subject	Teaching Experience	Education	Indigenous/Local Knowledge Context
T02	West Lombok	Senior secondary	Biology	8 years	Bachelor's	Local plants and their uses
T03	West Lombok	Senior secondary	Physics	15 years	Master's	Traditional architecture and pottery
T04	West Lombok	Junior secondary	Integrated Science	6 years	Bachelor's	Local food processing
T05	West Lombok	Senior secondary	Chemistry	10 years	Master's	Natural dyes and food fermentation
T06	Central Lombok	Junior secondary	Integrated Science	9 years	Bachelor's	Weaving and natural dyes
T07	Central Lombok	Senior secondary	Physics	13 years	Master's	Pottery and material firing
T08	Central Lombok	Senior secondary	Biology	7 years	Bachelor's	Local plants and agricultural ecology
T09	Central Lombok	Junior secondary	Integrated Science	11 years	Master's	Natural indicators of weather and seasons
T10	Central Lombok	Senior secondary	Chemistry	5 years	Bachelor's	Food processing and natural dyes
T11	East Lombok	Junior secondary	Integrated Science	14 years	Master's	Agricultural practices and water management
T12	East Lombok	Senior secondary	Biology	9 years	Bachelor's	Local plants and agricultural practices
T13	East Lombok	Senior secondary	Physics	16 years	Master's	Traditional architecture and traditional tools
T14	East Lombok	Junior secondary	Integrated Science	4 years	Bachelor's	Coastal and environmental practices
T15	East Lombok	Senior secondary	Biology	12 years	Master's	Local ecology, plants, and food practices

The variation represented in Table 1 enabled examination of translation practices across geographical settings, school levels, science disciplines, professional experience, and forms of locally grounded knowledge. The intention was not statistical representativeness but the inclusion of information-rich cases capable of revealing both common processes and meaningful variation.

Data Sources and Instruments

Data were generated through semi-structured interviews, instructional documents, selected classroom observations, and researcher field memos. Interviews constituted the primary source for reconstructing teachers' reasoning and decision-making. Instructional documents and classroom observations provided complementary evidence concerning how Indigenous knowledge was represented in instructional planning and enacted in classroom practice. Field memos supported reflexivity and documented the progressive development of analytical interpretations.

The semi-structured interview protocol contained 20 core questions organized around seven domains. The first domain explored teachers' experiences with local knowledge and their understanding of Indigenous knowledge in science education. Subsequent domains addressed identification and selection, interpretation in relation to scientific knowledge, epistemic negotiation and cultural sensitivity, pedagogical transformation, challenges and support, and reflection on the translation process. Probing questions were used to elicit concrete examples, decisions, rationales, and classroom consequences. The semi-structured format enabled the interviewer to follow relevant issues raised by participants without changing the substantive focus of the study.

The protocol deliberately avoided presenting participants with predefined epistemic categories. Terms such as *accepting*, *reinterpreting*, *contextualizing*, *challenging*, or *avoiding* were not offered as response categories. Instead, participants were encouraged to describe what they actually did when community-based explanations and formal scientific explanations did not fully correspond. This procedure was intended to allow epistemic patterns to emerge from participant accounts rather than be imposed during data collection.

Instructional document analysis was guided by a structured analytical form. Documents included lesson plans, teaching modules, student worksheets, presentation materials, a video resource, and a student task. Analysis considered the type and cultural context of Indigenous knowledge represented, the scientific concepts associated with it, the epistemic relationship constructed between local and scientific explanations, pedagogical transformation, cultural representation, available scientific or community references, possible simplification or misrepresentation, the positioning of students' family or community knowledge, and evidence of the translation process.

Classroom observations followed a structured non-participant protocol. Observation focused on how teachers introduced local contexts, related them to scientific concepts, differentiated or connected cultural and scientific explanations, responded to uncertainty or disagreement, organized learning activities, used local and scientific terminology, positioned sources of epistemic authority, incorporated students' experiences, and concluded relationships between Indigenous and scientific knowledge. The observations were intended to examine enacted translation rather than evaluate teacher performance.

Researcher field memos were produced following interviews, document analysis, and observations. The memo format distinguished descriptive information from preliminary interpretation and documented emerging patterns, contradictions, negative cases, researcher assumptions, and questions requiring further examination. Field memos therefore served both an analytical and reflexive function. The scope and analytical role of each source are summarized in Table 2.

Table 2. Data Sources, Coverage, and Analytical Focus

Data Source	Coverage	Main Analytical Focus	Analytical Role
Semi-structured interviews	15 teachers; 20 core questions	Encounter with community knowledge, selection, scientific interpretation, epistemic negotiation, pedagogical transformation, representation, challenges, and reflective accounts of translation	Primary evidence for reconstructing teacher reasoning and translation processes
Instructional documents	26 documents from 15 cases: 7 lesson plans, 7 modules, 6 student worksheets, 4 presentation files, 1 video, and 1 student task	Cultural context, scientific concepts, epistemic relationship, pedagogical transformation, representation, and evidence of translation	Corroborating, extending, or contrasting reported practices
Classroom observations	7 selected cases; 21 analytical episodes	Enacted representation of local knowledge, scientific interpretation, epistemic negotiation, pedagogical activity, and classroom interaction	Examining how translation was enacted in classroom practice
Researcher field memos	Produced in association with interviews, document analysis, and observations	Emerging interpretations, contradictions, negative cases, reflexivity, and follow-up questions	Supporting reflexive analysis and maintaining the analytical audit trail

Data Collection Procedures

Data collection was organized around the development of an individual case record for each teacher. Participant profiles were first documented to establish the educational, disciplinary, and professional context of each case. Semi-structured interviews were subsequently conducted to reconstruct teachers' experiences of using Indigenous or locally grounded knowledge in science teaching. Audio recording was undertaken with participant permission to support accurate transcription and analysis.

Interview probing focused on actual experiences rather than hypothetical attitudes. Teachers were encouraged to identify specific practices they had used, explain why particular forms of local knowledge had been selected or rejected, identify sources used when constructing scientific interpretations, and clarify how they responded when community explanations and formal scientific explanations differed.

Instructional materials were then collected from participating teachers. Twenty-six documents were available across the 15 cases, consisting of seven lesson plans, seven teaching modules, six student worksheets, four presentation files, one video resource, and one student task. The documents were examined not simply to establish whether local content appeared but to determine how that content was positioned pedagogically and epistemically. Particular attention was given to whether Indigenous knowledge remained an introductory example or was developed into questions, inquiry, analysis, comparison, tasks, or other substantive forms of science learning.

Classroom observations were conducted in seven selected cases: T01, T03, T05, T07, T09, T11, and T13. These cases generated 21 analytical observation episodes. For analysis, observed classroom events were organized around lesson opening, exploration, and discussion. This enabled examination of how locally grounded knowledge entered classroom discourse, how it became an object of scientific interpretation, and how differences between cultural and scientific explanations were negotiated during interaction.

The observational evidence was treated as case-specific corroborative and elaborative material rather than as direct evidence of enacted practice for all 15 teachers. This distinction was important because classroom observation covered only a purposively selected subset of the cases.

Field memos were generated alongside the primary data sources to preserve contextual observations and document the development of researcher interpretation. Particular attention was given to instances in which evidence from one source did not correspond fully with another. Such differences were not automatically treated as errors. They were retained for examination during within-case analysis, cross-case comparison, and triangulation.

Data Analysis

Data analysis was iterative and combined systematic qualitative coding with within-case and cross-case comparison (Miles et al., 2020; Saldaña, 2021; Yin, 2018). The analytical purpose was to reconstruct how teachers translated Indigenous knowledge without assuming that all cases would follow an identical trajectory. The research questions provided broad analytical direction, while coding and category development remained responsive to the empirical material, including contradictory and deviant evidence.

Analysis began with repeated reading of interview material, instructional documents, observation records, and field memos. During familiarization, attention was directed to actions, decisions, rationales, sources of knowledge, forms of verification, epistemic tensions, pedagogical transformations, and representations used in classroom science.

For systematic tabulation, the interview material was organized into 90 meaning units distributed across the 15 cases. These meaning units represented six broad analytical domains concerned with encountering local knowledge, selecting knowledge for classroom use, interpreting relationships across knowledge systems, negotiating epistemic differences, transforming knowledge pedagogically, and representing it in classroom science. The meaning units served as manageable analytical segments while remaining linked to their respective cases and original contexts.

Initial or open coding remained close to participants' accounts and recorded practices. The coding emphasized actions and decisions rather than assigning participants immediately to predefined typologies. Codes were subsequently compared across cases and refined through focused category development. Conceptually similar codes were consolidated, while analytically distinct forms of teacher decision-making were separated. For example, a teacher's reason for selecting a local practice was distinguished from the subsequent process through which the practice was interpreted scientifically. Similarly, recognizing an epistemic difference was distinguished from the way the teacher responded to that difference.

Within-case analysis was then undertaken for each participant. Available interview, document, observation, and field-memo evidence was integrated into a case summary describing the local knowledge context, selection decisions, mode of scientific interpretation, response to epistemic difference, pedagogical transformation, classroom representation, and relevant constraints. Maintaining case-level integrity reduced the risk of fragmenting participants' experiences into disconnected thematic excerpts.

Cross-case analysis compared the 15 case summaries to identify recurrent configurations, differences, contradictions, and deviant cases. Comparison focused on where cases converged and where teachers facing broadly similar translational problems made different epistemic or pedagogical decisions. Differences between interview accounts and documentary or observational evidence were retained rather than automatically reconciled because such differences could reveal distinctions between reported, planned, documented, and enacted practice.

Higher-order themes were developed by examining conceptual relationships among focused codes and recurrent cross-case patterns. Theme development was based on explanatory relevance rather than numerical prevalence. Because the analytical structure deliberately examined comparable translation domains across all 15 cases, frequencies were used primarily as an audit device and were not interpreted as measures of thematic importance. Greater analytical weight was placed on the quality and consistency of evidence, relationships among processes, cross-case variation, negative cases, and convergence or discrepancy among sources.

The overall relationship among data sources, analytical procedures, cross-case interpretation, and the development of the empirical model is illustrated in Figure 1.

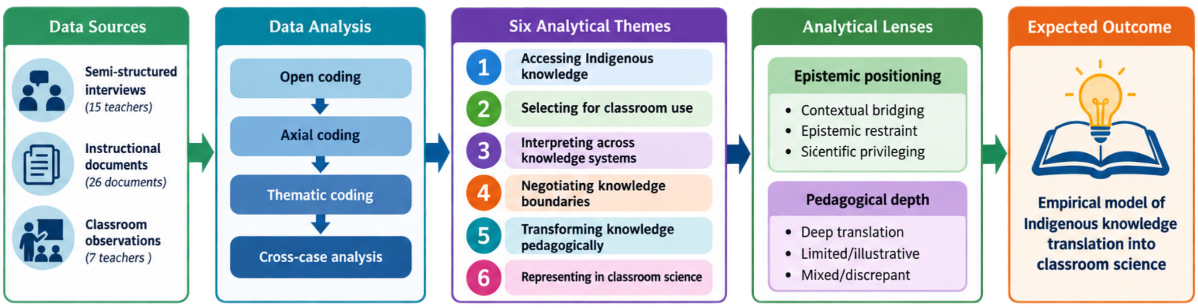

Figure 1. Integrated analytical framework linking multiple data sources, within-case and cross-case analytical procedures, and interpretive outputs

In the final stage, relationships among the higher-order themes were examined to determine whether the evidence supported an empirical process model of Indigenous knowledge translation into classroom science. Model development was explanatory rather than prescriptive. The resulting structure was intended to account for recurrent processes and variation evident across the cases rather than define a universal sequence that science teachers should follow. Table 3 summarizes the analytical stages and their principal outputs.

Table 3. Stages of Qualitative Data Analysis

Analytical Stage	Analytical Procedure	Primary Analytical Output
Data familiarization	Repeated reading of interview material, instructional documents, observation records, and field memos	Contextual understanding of each case and preliminary analytical notes
Initial/open coding	Coding actions, decisions, reasons, tensions, sources of knowledge, and pedagogical practices	Initial case-linked codes
Focused category development	Comparing, refining, separating, and consolidating initial codes according to analytical meaning	Focused codebook and provisional categories
Within-case analysis	Integrating evidence associated with each teacher across available sources	Individual case summaries
Cross-case comparison	Comparing recurrent patterns, variations, contradictions, and deviant cases across the 15 cases	Cross-case analytical matrix
Theme development	Examining conceptual relationships among focused categories and recurrent cross-case patterns	Higher-order themes
Triangulation and analytical refinement	Comparing interview, document, observation, and field-memo evidence and revisiting interpretations where necessary	Refined interpretations and documented analytical decisions
Empirical model development	Synthesizing relationships and recurring processes supported across cases and data sources	Empirically grounded translation model

Although Table 3 presents the analytical process sequentially for clarity, analysis was recursive. Coding definitions, case interpretations, and emerging relationships were revisited as additional evidence was compared across data sources and cases. Model development therefore represented the culmination of iterative analysis rather than a predetermined analytical target into which the data were fitted.

Trustworthiness and Reflexivity

Trustworthiness was addressed through source triangulation, explicit attention to negative and deviant cases, maintenance of an analytical audit trail, and reflexive memo writing, consistent with established principles of qualitative inquiry (Lincoln & Guba, 1985; Tracy, 2010).

Triangulation was not treated simply as a search for agreement. Interview evidence was compared with instructional documents and, for the seven observed cases, classroom observation evidence. Convergence across sources strengthened particular interpretations, while inconsistencies prompted renewed examination of the case. Documents and observations could therefore confirm, elaborate, qualify, or challenge interview-based interpretations.

The analysis deliberately retained contradictory and deviant evidence. Emerging patterns were not accepted simply because they represented the majority of participants. Cases that differed in scientific interpretation, epistemic positioning, or pedagogical representation were examined to refine the boundaries of emerging categories. Similarly, differences among reported, documented, and observed practices were regarded as potentially meaningful rather than automatically corrected to produce artificial consistency.

An analytical audit trail documented major decisions made during coding, category refinement, theme development, and model construction. This record included changes to coding definitions, separation or consolidation of conceptually related categories, attention to contradictory evidence, and reconsideration of earlier interpretations. The audit trail enabled the analytical progression from meaning units to case summaries, cross-case comparison, higher-order themes, and empirical model development to remain traceable.

Reflexive field memos complemented the audit trail by recording researcher assumptions, preliminary interpretations, unresolved questions, reactions to particular cases, and possible influences on meaning-making. Reflexivity was especially important because research involving Indigenous and scientific knowledge carries a risk of implicitly treating school science as the default epistemic standard against which other forms of knowledge are evaluated. The analysis therefore did not assume that Indigenous knowledge should always be verified or validated exclusively through scientific knowledge. Instead, it examined empirically how teachers connected, distinguished, maintained, transformed, or prioritized different forms of knowledge and how these decisions shaped classroom science.

Ethical Considerations

Ethical procedures were guided by principles of voluntary participation, informed consent, confidentiality, anonymity, and respectful representation of culturally situated knowledge. Participants were informed about the purpose of the study and the nature of their participation before data collection. Participation was voluntary, and teachers could permit or decline audio recording. Anonymous case codes were used in the analytical dataset and manuscript rather than personal names.

Ethical consideration also extended to the treatment of Indigenous knowledge itself. Moving knowledge from community contexts into research and formal education can introduce risks of simplification, decontextualization, appropriation, or misrepresentation. The analysis therefore did not assess locally grounded knowledge solely according to its correspondence with school science. Attention was given to how cultural origins, terminology, community meanings, and epistemic boundaries were maintained or transformed when Indigenous knowledge entered instructional materials and classroom interaction.

RESULTS AND DISCUSSION

Overview of the Indigenous Knowledge Translation Process

Cross-case analysis of the 15 teacher cases showed that translating Indigenous knowledge into classroom science was not a single act of inserting local examples into existing science content. Instead, the data revealed a recurrent process involving six interconnected forms of teacher activity: accessing Indigenous knowledge, selecting knowledge for classroom use, interpreting it across knowledge systems, negotiating knowledge boundaries, transforming knowledge pedagogically, and representing it in classroom science.

The six processes were identified across all cases because the analysis examined comparable domains for every participant. Their equal representation should therefore not be interpreted as equivalent frequency or importance. The substantive findings emerged from how teachers enacted each process, how decisions at one stage influenced subsequent stages, and how cases differed in epistemic positioning and pedagogical depth.

The six higher-order themes and their dominant empirical patterns are summarized in Table 4.

Table 4. Themes and Main Empirical Patterns in Indigenous Knowledge Translation

Theme	Central Analytical Focus	Main Empirical Pattern	Cases Represented
Accessing Indigenous Knowledge	How local knowledge entered teachers' professional awareness	Knowledge was encountered through family, community, local environments, cultural practices, and students' experiences	15
Selecting for Classroom Use	How teachers determined whether local knowledge was suitable for science teaching	Selection was primarily based on curricular relevance and familiarity to students	15
Interpreting Across Knowledge Systems	How local knowledge was related to scientific concepts	Teachers either interpreted practices complementarily through science or explicitly limited scientific reduction	15
Negotiating Knowledge Boundaries	How teachers responded when local and scientific explanations differed	Most cases contextualized differences, whereas a smaller group gave school science greater epistemic authority	15
Transforming Knowledge Pedagogically	How local knowledge became a learning activity	Most teachers reframed local knowledge for inquiry, analysis, or comparison, while some used it mainly as illustration	15
Representing in Classroom Science	How Indigenous and scientific knowledge	Local experience generally preceded formal scientific	15

Theme	Central Analytical Focus	Main Empirical Pattern	Cases Represented
	were sequenced in teaching	explanation and subsequent comparison	

Taken together, the themes indicate that Indigenous knowledge translation involved several layers of decision-making. Teachers first decided what knowledge could enter the classroom, then determined how that knowledge should relate to scientific knowledge, and finally decided what pedagogical form it should take once it entered instruction. Variation was relatively limited during accessing and selecting but became more pronounced during interpretation, epistemic negotiation, and pedagogical transformation.

The interview excerpts reported below were translated from Indonesian into English for presentation in the manuscript while retaining the substantive meaning of participants' statements.

Accessing and Selecting Indigenous Knowledge

Across all 15 cases, Indigenous knowledge initially entered teachers' professional awareness through social and cultural experience rather than through formal science curriculum materials. Teachers referred to family practices, community knowledge, local environments, students' experiences, and cultural activities as important sources through which locally grounded knowledge became visible as a possible resource for science teaching.

T01, for example, described how familiarity with traditional Sasak architecture originated outside formal schooling but subsequently became pedagogically meaningful when students brought the context into classroom discussion:

> *"I first learned about the form and ventilation of traditional Sasak architecture from my family and the community around the school. When students mentioned it during lessons, I began to see that traditional Sasak architecture could become an entry point for science concepts." (T01)*

A comparable process occurred in other cases with different cultural contexts. T11 described local agricultural and water-management practices as knowledge initially encountered through family and community life, while T14 referred to coastal and environmental practices in the same way. Thus, what eventually appeared as classroom content usually originated as socially embedded knowledge.

However, familiarity alone was insufficient. Teachers described a subsequent selection process in which only certain elements of local knowledge were taken into science instruction. T01 explained:

> *"I do not include every aspect of traditional Sasak architecture. I select those that are close to students' experiences and have a sufficiently clear relationship with the competencies currently being studied." (T01)*

T05 reported the same reasoning in relation to natural dyes and food fermentation, indicating that local practices were selected when they could be connected meaningfully with the science curriculum. Across the cases, two considerations repeatedly shaped this decision: students' familiarity with the context and its curricular relevance.

The distinction between accessing and selecting was therefore empirically clear. Teachers could be familiar with many forms of Indigenous knowledge but only translated those that they considered sufficiently teachable within the science curriculum. Community familiarity made the knowledge available, while curricular relevance determined whether it progressed into formal instruction.

Interpreting Indigenous Knowledge Across Knowledge Systems

Greater variation emerged when teachers attempted to interpret selected Indigenous knowledge through scientific concepts. Eleven of the 15 cases predominantly demonstrated a complementary interpretive pattern. These teachers consulted textbooks or other scientific sources and identified aspects of local practices that could be connected with formal science while retaining locally recognizable terminology and context.

T01 described this process as follows:

> *"I usually read the concepts in the textbook again and compare them with how the community explains the form and ventilation of traditional Sasak architecture. I use the parts that can be explained through science concepts, but I still retain the local terms." (T01)*

This approach was also evident in cases involving natural dyes, food processing, plants, agricultural practices, environmental phenomena, and other contexts. Scientific knowledge functioned as an interpretive resource rather than as an automatic replacement for locally situated knowledge.

Four cases, T03, T07, T11, and T13, demonstrated a more explicitly bounded pattern. These teachers distinguished between aspects of local practice that they considered open to scientific examination and cultural meanings that they did not consider necessary to translate into scientific concepts. This pattern was identified as epistemic restraint.

T03 explained this distinction when discussing traditional building stability and pottery:

> *"For building stability and pottery, I check the concepts from several sources and sometimes discuss them with other teachers. I try to separate the parts of the practice that can be tested from cultural meanings that do not need to be forced into science concepts." (T03)*

T11 expressed the same position regarding water management and agricultural practices, while T13 applied it to traditional tools and architecture. T13 stated:

> *"For traditional tools and architecture, I check the concepts from several sources and sometimes discuss them with colleagues. I try to distinguish the parts of the practice that*

can be tested from cultural meanings that do not need to be forced into science concepts." (T13)

The cross-case distinction therefore did not concern whether teachers used scientific knowledge. All teachers did so. Rather, the difference concerned how far scientific interpretation was allowed to extend. In the complementary cases, teachers primarily sought a meaningful connection with science. In the epistemic-restraint cases, teachers additionally established limits around what could legitimately be transformed into scientific explanation.

These findings indicate that translation did not necessarily mean converting Indigenous knowledge in its entirety into scientific knowledge. For several teachers, responsible translation involved determining which dimensions could be scientifically examined while allowing other dimensions to remain culturally situated.

Negotiating Knowledge Boundaries

The most pronounced epistemic variation emerged when local explanations and scientific explanations did not fully correspond. Twelve cases demonstrated forms of contextual negotiation rather than immediate rejection of community explanations.

Teachers in these cases differentiated between community interpretations and formal scientific explanations while allowing both to become visible during classroom discussion. T03 described this approach explicitly:

"Sometimes the reasons given by the community differ from the scientific explanation. I do not immediately say that the local knowledge is wrong. I explain that this is how the community makes sense of its experience, and then we compare it with scientific evidence." (T03)

The same pattern appeared across cases involving biology, chemistry, physics, and integrated science. The important feature was that epistemic difference became an object of comparison rather than an error that had to be immediately corrected.

Within these cases, eight teachers, T01, T02, T05, T06, T08, T09, T12, and T15, predominantly demonstrated contextual bridging. Local and scientific explanations were connected and compared while remaining distinguishable. Four cases, T03, T07, T11, and T13, demonstrated epistemic restraint, in which comparison was accompanied by an explicit recognition that some dimensions of cultural knowledge should remain outside scientific reduction.

A contrasting pattern appeared in T04, T10, and T14. These cases demonstrated scientific privileging, where school science became the primary epistemic reference when explanations diverged.

T04 stated:

"When the local explanation differs from the textbook, I still tend to use the textbook explanation as the main reference. I mention the local context, but I usually do not discuss it very deeply because the time is limited." (T04)

T10 reported a comparable position when discussing material changes in local food processing. Although local knowledge was still used as an instructional context, scientific explanations retained greater authority when conflict occurred. The resulting cross-case patterns are shown in Table 5.

Table 5. Cross-Case Patterns of Epistemic Positioning

Epistemic Position	Cases	Main Characteristic
Contextual bridging	T01, T02, T05, T06, T08, T09, T12, T15	Local and scientific explanations were connected and compared contextually without automatically dismissing local knowledge.
Epistemic restraint	T03, T07, T11, T13	Scientific interpretation was applied selectively, while cultural meanings considered unsuitable for scientific verification were not reduced to school-science explanations.
Scientific privileging	T04, T10, T14	Indigenous knowledge remained visible, but school science held primary epistemic authority when explanations diverged.

These positions represented different ways of handling epistemic difference rather than different levels of willingness to use Indigenous knowledge. Teachers in all three categories brought local knowledge into science instruction. What varied was how explanatory authority was distributed when the two knowledge systems did not align.

Transforming Indigenous Knowledge Pedagogically

The fifth process concerned what teachers did pedagogically after local knowledge had been selected and interpreted. Interview evidence indicated that 13 of the 15 teachers described transforming local contexts into inquiry, observation, prediction, analysis, comparison, or related student activities.

T05 explained the intended transformation clearly:

> *"So that it does not become only a cultural story, I turn the local context into an investigative question. Students are asked to observe, make predictions, and connect their results with the concept being studied." (T05)*

The wording emphasizes a shift from Indigenous knowledge as information to Indigenous knowledge as an object of student reasoning. Similar accounts occurred in cases involving architecture, pottery, plants, fermentation, agriculture, and environmental phenomena.

T03 likewise reported:

> *"So that it does not become only a cultural story, I transform the local context into an investigative question. Students are asked to observe, make predictions, and relate their findings to the concept being studied." (T03)*

This process was identified as pedagogical reframing because local knowledge no longer functioned merely as cultural background. Instead, teachers transformed it into questions or activities requiring students to observe, interpret, compare, or explain.

Two cases, T06 and T14, demonstrated a different pattern. Their interview accounts indicated that local knowledge was used primarily as an example or lesson introduction rather than developed into a specific inquiry activity.

T06 explained:

> *"I usually use the context as an example or as an introduction to the lesson. I have not yet developed a specific experiment because teaching materials and classroom time are limited." (T06)*

T14 reported the same constraint in relation to coastal and environmental practices:

> *"I usually use the context as an example or as an introduction. I have not yet developed a specific experiment because teaching materials and instructional time are limited." (T14)*

Instructional-document analysis supported this distinction. Twenty-three of the 26 documents showed local contexts extending into subsequent analytical activities. Three documents, associated with T06, T10, and T14, remained predominantly illustrative.

T10 presented an analytically important discrepancy. In the interview, T10 described a substantially deeper transformation:

> *"So that it does not become only a cultural story, I turn the local context into an investigative question. Students are asked to observe, make predictions, and connect their results with the concepts being studied." (T10)*

However, the available worksheet represented local food-processing knowledge mainly as an introductory context rather than as the basis of sustained inquiry. The interview and documentary evidence were therefore not forced into agreement. T10 was retained as a mixed or discrepant case, indicating different levels of translation across reported and documented practice. Cross-case comparison produced the three patterns summarized in Table 6.

Table 6. Cross-Case Patterns of Pedagogical Depth

Pedagogical Depth	Cases	Empirical Characteristic
Deep translation	T01, T02, T03, T04, T05, T07, T08, T09, T11, T12, T13, T15	Indigenous knowledge became the basis for inquiry, analysis, comparison, explanation, or other substantive learning activities
Limited/illustrative translation	T06, T14	Indigenous knowledge functioned primarily as an example, introductory context, or aperception
Mixed/discrepant translation	T10	Reported practice indicated deeper pedagogical reframing than was evident in the available instructional document

A particularly important cross-case finding was that epistemic positioning and pedagogical depth were not the same dimension. T04 demonstrated scientific privileging during epistemic negotiation but nevertheless reported relatively substantial pedagogical reframing. In contrast, T06 demonstrated contextual bridging yet used Indigenous knowledge largely as an illustrative context.

Representing Indigenous Knowledge in Classroom Science

A highly consistent pattern appeared in how teachers described the sequencing of Indigenous and scientific knowledge during classroom instruction. All 15 cases reported beginning with phenomena familiar to students before moving toward formal scientific terminology and explanation.

T13 described the instructional sequence as follows:

"In class, I show a familiar photograph or object, and the students first explain it based on their experience. Only after that do we move to scientific terms and explanations." (T13)

T01 described essentially the same sequencing for traditional Sasak architecture:

"In class, I show a familiar photograph or object, and the students explain it first based on their experience. After that, we move to scientific terms and explanations." (T01)

This pattern was identified as local-to-scientific sequencing. The classroom did not necessarily begin with a formal scientific definition followed by a cultural example. Instead, teachers generally began with locally recognizable experience and used it as an entry point into scientific interpretation.

Classroom observations of T01, T03, T05, T07, T09, T11, and T13 strengthened this finding. The seven cases generated 21 analytical observation episodes organized around lesson opening, exploration, and discussion. During lesson openings, teachers introduced locally familiar objects, images, practices, or phenomena and invited students to contribute experiences from family or community life. Formal scientific explanations were generally withheld initially. During exploration, the local phenomenon became an object of analysis. Students compared characteristics or processes through guiding questions, while scientific concepts began to function as interpretive tools. During discussion, teachers connected the phenomenon to formal science and addressed differences between local and scientific explanations. The observed sequence can therefore be summarized as local experience, inquiry or analysis, scientific interpretation, and epistemic comparison.

The observations did not provide direct evidence for all 15 participants because only seven cases were observed. However, the consistency between interview and observation evidence in the selected cases strengthened the interpretation that local-to-scientific sequencing constituted an important feature of enacted translation.

Cross-Source Convergence and Discrepancy

Comparison across interviews, instructional documents, and classroom observations revealed substantial convergence while also demonstrating the analytical value of maintaining multiple sources of evidence. Twenty-three of the 26 instructional documents supported the interpretation that Indigenous knowledge functioned as more than a cultural reference because locally grounded phenomena were connected with student questions, analysis, explanation, comparison, or other instructional tasks. For the seven teachers who were observed, the 21 classroom episodes were likewise broadly consistent with the corresponding interview accounts. In these observed cases, teachers commonly introduced familiar local experiences, engaged students in analytical activity, and then moved toward scientific interpretation and, where relevant, epistemic comparison. This convergence increased confidence that the translation processes identified in the interviews were not limited to retrospective descriptions but were also visible in instructional planning and classroom enactment. At the same time, the analysis did not treat agreement across sources as a requirement for a valid interpretation, because discrepancies could reveal important differences among reported, documented, and enacted practice.

The most informative discrepancy occurred in T10. The interview account suggested inquiry-oriented pedagogical transformation, whereas the available instructional document represented Indigenous knowledge primarily as an illustrative context. Rather than forcing these sources into agreement, the difference was retained as evidence that translation can operate differently across layers of teaching practice. What teachers intend or report doing may not always be reproduced with the same depth in the materials they prepare, and a single document may not capture the full range of classroom practice. T06 and T14 showed a different pattern because interview and documentary evidence converged more consistently around limited pedagogical transformation. In these cases, Indigenous knowledge was present but remained mainly an example, introductory context, or point of familiarity rather than becoming a sustained object of inquiry or analysis. Cross-source comparison therefore sharpened an important distinction in the findings: the relevant issue was not simply the presence or absence of Indigenous knowledge, but the degree to which locally grounded knowledge was transformed after entering classroom instruction.

An Empirical Model of Indigenous Knowledge Translation into Classroom Science

Cross-case synthesis resulted in an empirical model consisting of six interconnected processes: accessing, selecting, interpreting, negotiating, transforming, and representing Indigenous knowledge in classroom science. The first three processes describe how locally grounded knowledge becomes available for instructional use and how teachers initially position it in relation to school science. Accessing refers to the ways knowledge entered teachers' professional awareness through family, community, local environments, cultural practices, and students' experiences. Selecting occurred when teachers evaluated whether particular knowledge was sufficiently familiar to students, relevant to the curriculum, and potentially useful for learning. Interpreting involved establishing relationships between selected Indigenous knowledge and scientific concepts. Most teachers constructed complementary relationships by identifying scientifically interpretable aspects of local practices, whereas a smaller group deliberately limited the reach of scientific interpretation so that cultural meanings were not unnecessarily reduced. These early stages show that knowledge did not enter classroom science automatically; it was progressively filtered, interpreted, and bounded through teacher judgment before becoming an instructional resource.

The latter three processes describe how these initial judgments became epistemically and pedagogically consequential in classroom practice. Negotiating became necessary when local and scientific explanations did not fully correspond. At this point, three empirical positions emerged: contextual bridging, epistemic restraint, and scientific privileging. These positions reflected different ways of managing explanatory difference and assigning authority across knowledge systems. Transforming concerned the pedagogical form given to the selected and interpreted knowledge. Most teachers described reframing local phenomena as material for inquiry, analysis, comparison, observation, or explanation, while a smaller number used Indigenous knowledge mainly as an example or lesson introduction. Representing concerned how these decisions were ultimately sequenced and made visible during instruction. Across cases, teaching generally began with familiar local experience and then moved toward formal scientific interpretation, with the more developed cases creating opportunities for students to compare explanations and examine epistemic relationships rather than simply replacing local understandings with canonical science.

The empirical model should not be interpreted as a rigid or entirely linear sequence. Evidence across the cases showed that teachers could revisit earlier decisions when difficulties or tensions emerged at later stages. For example, difficulty transforming a local practice into a meaningful learning activity could lead a teacher to reconsider its curricular suitability, while epistemic tensions arising during classroom discussion could prompt renewed interpretation of the relationship between local and scientific explanations. Two dimensions of cross-case variation operated across this recursive process. The first was epistemic positioning, represented by contextual bridging, epistemic restraint, and scientific privileging. The second was pedagogical depth, represented by deep translation, limited or illustrative translation, and mixed or discrepant translation. Importantly, these dimensions were related but not equivalent. The model therefore captures translation as a combined epistemic-pedagogical process in which teachers make repeated decisions about relevance, interpretation, authority, transformation, and representation as Indigenous knowledge moves from community contexts into classroom science.

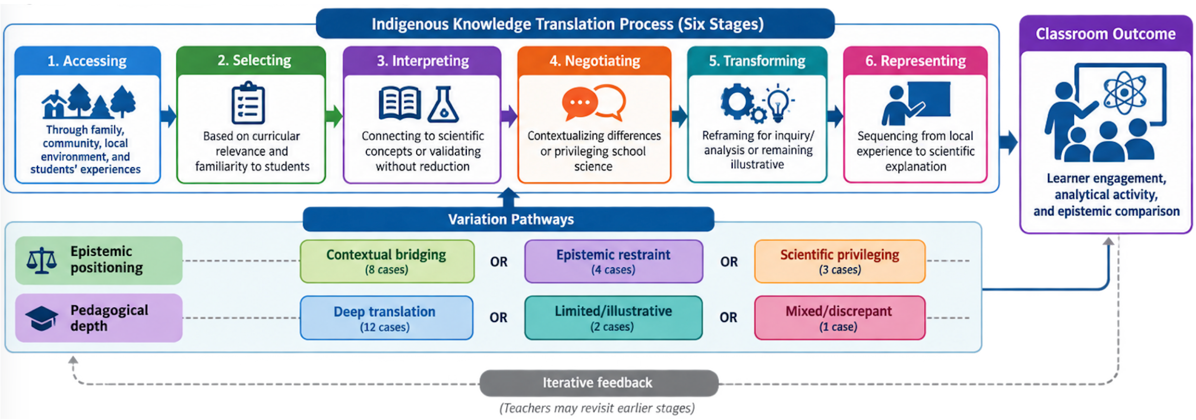

Figure 2. Empirical model of Indigenous knowledge translation into classroom science

Figure 2 synthesizes the six interconnected processes and the two dimensions of cross-case variation into the empirical model of Indigenous knowledge translation. As represented in Figure 2, the six-stage translation process provides a common analytical structure across cases, while the epistemic and pedagogical pathways account for variation in how teachers moved through that structure. The model therefore does not imply that Indigenous knowledge undergoes a uniform conversion into scientific knowledge. Rather, it shows that teachers continually make decisions about what knowledge should enter instruction, which aspects can be interpreted scientifically, how differences between knowledge systems should be negotiated, and how selected knowledge should ultimately be transformed and represented in classroom activity. The iterative feedback component further indicates that decisions made at later stages may lead teachers to reconsider earlier ones, reinforcing the interpretation of translation as a recursive rather than mechanically sequential process. Taken together, these relationships position Indigenous knowledge translation as a combined cultural, epistemic, and pedagogical process, with the final classroom representation reflecting both the teacher's epistemic positioning and the depth of pedagogical transformation achieved.

Discussion

The central finding of this study is that the movement of Indigenous knowledge into classroom science is better understood as a process of translation than as a simple act of integration. Across the 15 cases, teachers did not merely identify culturally familiar examples and attach them to established science content. They made successive decisions concerning which knowledge was relevant, which elements could be related to scientific concepts, where epistemic boundaries should be maintained, how disagreements between knowledge systems should be handled, and how selected knowledge should eventually be transformed into classroom activity. The six processes identified in this study, accessing, selecting, interpreting, negotiating, transforming, and representing, therefore make visible forms of teacher reasoning that are obscured when Indigenous knowledge is described only as something that is integrated into science education.

This interpretation builds on, but also extends, the cultural-border-crossing tradition in science education. Aikenhead (1996) conceptualized science learning as movement between students' everyday cultural worlds and the subculture of school science, while Aikenhead and Michell (2011) later emphasized the importance of respectfully bridging Indigenous and scientific ways of knowing nature. Related work has shown that science education may involve negotiation among potentially different explanatory worlds rather than straightforward replacement of everyday knowledge by canonical science (Costa, 1995; Jegede, 1995). The present findings add a teacher-centered dimension to this argument. Before students encounter different knowledge systems in classroom discourse, teachers have already made decisions about which knowledge can cross into school science, which dimensions should be reinterpreted, and what epistemic form the translated knowledge should take. Teachers are therefore involved not only in facilitating border crossing but also in constructing the conditions under which that crossing occurs.

The language of translation is also consistent with wider scholarship on relations among knowledge systems. Whyte (2013) argues against treating traditional ecological knowledge as a static collection of facts detached from relationships and practices, while Tengö et al. (2017) describe processes of mobilizing, translating, negotiating, synthesizing, and applying knowledge across systems. These perspectives are relevant to the Lombok cases because Indigenous knowledge did not move intact from community contexts to formal science instruction. Selection and transformation occurred at several points. What finally appeared in the classroom represented the outcome of teacher decisions rather than a direct transfer of cultural content.

This distinction matters because Indigenous knowledge is embedded in practices, social relationships, places, institutions, and worldviews rather than consisting solely of isolated empirical observations (Barnhardt & Kawagley, 2005; Berkes, 2018; Snively & Corsiglia, 2001). Translating a cultural practice exclusively into scientific concepts can therefore alter what counts as relevant knowledge. A traditional building may become an example of heat transfer or structural stability; fermentation may become biochemical change; a seasonal indicator may become an environmental observation. These interpretations can be educationally useful, but they represent only particular dimensions of the original practice. The translation perspective draws attention to what is preserved, what is transformed, and what disappears in this movement.

This argument also qualifies a growing body of research documenting the educational potential of local and Indigenous knowledge. Recent reviews show that Indigenous knowledge has been used internationally through contextualized materials, inquiry, experiential activities, argumentation, dialogue, and engagement with community knowledge holders (Latip et al., 2024; Ogegbo & Ramnarain, 2024). Such research demonstrates the pedagogical potential of culturally grounded science education, but the present findings indicate that instructional strategies are preceded by epistemic decisions about the knowledge being transformed. In the Indonesian context, studies have demonstrated the potential of local cultural knowledge as a source of science and chemistry learning, including culturally responsive and inquiry-based approaches (Rahmawati, Baeti, et al., 2019; Verawati et al., 2022). Research involving Sasak knowledge has similarly documented the potential of local practices as chemistry learning resources (Wahyudiati, 2022; Wahyudiati & Qurniati, 2023). The current study does not dispute this educational potential. Rather, it shifts the analytical question from whether Sasak knowledge can be used in science education to how teachers decide what happens to that knowledge when it becomes classroom science.

This difference is significant because cultural visibility alone does not demonstrate epistemically meaningful integration. A lesson can contain a traditional object, local plant, Indigenous practice, or community phenomenon while leaving the knowledge embedded in that practice peripheral to the intellectual work of the lesson. Seehawer (2018) similarly showed that Indigenous knowledge can remain an addition to a predominantly Western science curriculum even when teachers deliberately attempt integration. The limited-translation cases in the present study illustrate this possibility. Indigenous knowledge was culturally visible, but it mainly functioned as an introductory context. Translation therefore provides a more discriminating analytical category than presence or integration alone.

A second major insight concerns teachers' role as epistemic mediators. Teachers were not simply transforming subject matter pedagogically; they were making decisions about relationships between ways of knowing. The three cross-case patterns, contextual bridging, epistemic restraint, and scientific privileging, demonstrate that teachers did not position Indigenous and scientific knowledge uniformly. The contextual-bridging pattern supports arguments that science education can provide learners with opportunities to navigate multiple epistemologies rather than requiring one way of knowing to disappear when another is introduced (Bang & Medin, 2010). Teachers in this group retained sufficient distinction between local and scientific explanations to make comparison possible. They did not necessarily regard both explanations as equally adequate for all purposes. Instead, they avoided closing epistemic discussion prematurely.

This finding is also compatible with Ogunniyi's (2007a) analysis of teachers' stances toward science-Indigenous knowledge curricula. Teachers' positions toward knowledge systems affect the arguments and pedagogical decisions through which Indigenous knowledge becomes part of science instruction. More recent research similarly emphasizes that teacher perspectives remain central to how IKS is represented within STEM classrooms (Ogunniyi & Iwuanyanwu, 2024). The Lombok data extend this literature by showing that epistemic stance can be observed not only as a general attitude but also through specific decisions made at different stages of translation.

The three patterns identified here can also be compared with Naidoo and Vithal's (2014) distinction among incorporationist, separatist, and integrationist teacher approaches. Their work provides one of the closest empirical precedents for the present study because it demonstrates that teachers position Indigenous knowledge differently relative to school science. However, the current findings suggest that a single category may not fully describe a teacher's practice. Teachers may display one epistemic position when explanations conflict but a different level of depth when translating the same knowledge pedagogically. The process model therefore complements typological approaches by identifying where variation occurs during translation.

The epistemic-restraint pattern is especially significant. T03, T07, T11, and T13 actively related local practices to scientific concepts but resisted translating every cultural dimension into science. Their stance resembles scholarship advocating engagement among knowledge systems without requiring one to become the universal evaluator of another. The Multiple Evidence Base approach proposes that different knowledge systems can contribute complementary evidence while maintaining their own processes of knowledge validation

(Tengö et al., 2014). Two-Eyed Seeing similarly encourages engagement with strengths from Indigenous and mainstream traditions without requiring epistemic assimilation (Bartlett et al., 2012).

Epistemic restraint therefore represents more than reluctance to explain cultural knowledge scientifically. It involves recognition that scientific interpretability has limits. This is important because the inclusion of Indigenous knowledge can remain epistemically assimilationist even when conducted with culturally respectful intentions. If a traditional practice is considered educationally legitimate only once a corresponding scientific concept has been identified, scientific knowledge still determines what part of Indigenous knowledge is worthy of classroom recognition. Andreotti et al. (2011) warn that epistemological pluralism generates precisely this type of ethical and pedagogical challenge when one epistemology is positioned as the standard through which another must become intelligible.

At the same time, the relationship between Indigenous and scientific knowledge should not be represented as an absolute binary. Agrawal (1995) cautions against constructing overly rigid divisions between Indigenous and scientific knowledge because knowledge traditions are historically dynamic and can interact in complex ways. The contextual-bridging cases support this point. Teachers did not always encounter two completely independent systems. Local practices and formal scientific explanations could overlap, interact, and become mutually relevant within particular instructional contexts.

The scientific-privileging cases should likewise not be interpreted simply as pedagogical failure. Teachers work within an institution in which formal science is embedded in curriculum documents, textbooks, examinations, disciplinary expectations, and professional accountability. The greater authority assigned to school science by T04, T10, and T14 may therefore reflect both epistemic beliefs and institutional pressures. Recent studies report that teachers attempting to integrate Indigenous knowledge encounter limitations involving knowledge, curriculum requirements, teaching materials, practical work, time, and sociocultural considerations (Mkhwebane, 2024; Mlotshwa & Tsakeni, 2024). Scientific privileging should consequently be interpreted as a situated instructional response rather than only an individual deficit.

The three epistemic positions are thus best viewed descriptively rather than normatively. Contextual bridging is not automatically superior in every instructional situation, epistemic restraint does not imply rejection of science, and scientific privileging does not necessarily entail rejection of Indigenous knowledge. Each pattern represents a different response to the educational problem of what teachers should do when knowledge systems do not provide identical explanations.

A further finding of particular importance is that epistemic positioning and pedagogical depth were related but empirically distinct. A straightforward assumption would be that teachers who show greater epistemic openness toward Indigenous knowledge would also translate it more deeply into classroom activity. The cases did not consistently support this assumption. T04 provides the clearest example. Although formal scientific knowledge was privileged when explanatory differences emerged, the Indigenous context was nevertheless transformed into substantive instructional activity. T06 showed a different configuration: contextual bridging was evident at the epistemic level, but the local context remained largely illustrative pedagogically. These contrasting cases show that respectful epistemic positioning alone does not generate sophisticated pedagogy, just as sophisticated pedagogical activity does not necessarily imply epistemic parity between knowledge systems.

The distinction can be interpreted through research on teacher knowledge and pedagogical reasoning. Shulman (1986, 1987) conceptualized teaching as a process in which teachers transform subject matter into representations, explanations, examples, activities, and forms that become accessible to learners. From this perspective, translating Indigenous knowledge requires specialized pedagogical reasoning in addition to an epistemic stance toward cultural knowledge. Teachers must determine not simply whether a local practice deserves recognition but how it can become intellectually productive within instruction.

Research on science teachers' pedagogical content knowledge similarly suggests that the ability to transform content depends on an integrated professional knowledge base rather than content knowledge alone (Park & Oliver, 2008; van Driel et al., 1998). The current study extends this reasoning into Indigenous knowledge contexts. Teachers require what might be described as a dual capability: an epistemic capability to negotiate relations among knowledge systems and a pedagogical capability to transform culturally situated phenomena into meaningful science-learning experiences.

The distinction is also supported by culturally responsive science-education research. Brown and Crippen (2017) show that culturally responsive science teaching depends on teacher knowledge and specific practices, not merely positive orientations toward students' cultures. Broader research on culturally relevant education likewise indicates that cultural responsiveness requires changes in pedagogical practice rather than superficial incorporation of cultural references (Aronson & Laughter, 2016). Contemporary science-education scholarship similarly emphasizes that culturally responsive and sustaining pedagogy involves treating students' cultural resources as intellectual assets within curriculum and learning rather than decorative additions (Smith et al., 2022).

The contrast between deep and illustrative translation in the present study makes this distinction empirically visible. In deep translation, Indigenous knowledge altered the intellectual work required of students. It became an object of observation, inquiry, analysis, explanation, or epistemic comparison. In illustrative translation, it remained primarily a familiar context through which predetermined science content was introduced. Recent research on Indigenous knowledge integration supports the importance of this pedagogical distinction. Ogegbo and Ramnarain (2024) identify argumentation, experiential learning, contextualized materials, and involvement of knowledge holders among pedagogical practices used to integrate IKS. Mkhwebane (2024) likewise emphasizes the importance of teacher pedagogical knowledge and support in transforming Indigenous knowledge into culturally responsive science instruction. These findings suggest that meaningful integration depends on what teachers enable students to do intellectually with culturally grounded knowledge.

The discrepancy observed in T10 adds another dimension. The participant described inquiry-oriented transformation during the interview, whereas the available instructional document showed a more illustrative use. Such divergence suggests that epistemic-pedagogical translation may vary across intended, reported, planned, documented, and enacted practice. This should not simply be dismissed as inconsistency. It illustrates a broader challenge in culturally responsive education: teachers may endorse or describe particular practices but encounter difficulties reproducing those intentions consistently in curricular artifacts or classroom enactment.

This interpretation has consequences for teacher professional development. Training that merely introduces teachers to examples of local knowledge is unlikely to address the full translation problem. Teachers need support in both interpreting relations among knowledge systems and designing pedagogical representations through which those relations become intellectually productive. Research on professional development for culturally responsive science education similarly demonstrates the need for structured opportunities to develop teacher knowledge and instructional practice rather than assuming responsiveness emerges automatically from cultural awareness (Brown & Crippen, 2016).

The consistent local-to-scientific sequencing across cases provides another important insight. Teachers generally began with culturally familiar objects, practices, phenomena, or experiences before introducing formal scientific terminology. Among the observed cases, this frequently developed into inquiry or analysis followed by scientific interpretation and epistemic comparison. This sequence is consistent with asset-based perspectives on learning. The funds-of-knowledge tradition argues that households and communities contain historically accumulated bodies of knowledge that can function as resources for classroom learning rather than deficits to be replaced by formal schooling (Moll et al., 1992). Research in science education has similarly demonstrated how students' community experiences and discourses can create hybrid spaces in which everyday and scientific resources are mobilized jointly (Barton & Tan, 2009).

The findings from Lombok add an important teacher dimension to this argument. Teachers' own familiarity with community practices influenced which knowledge they recognized as educationally relevant. This interpretation is particularly compatible with recent work by Sealy et al. (2026), which shows that teachers' own funds of knowledge influence their ability to recognize and incorporate students' funds of knowledge into culturally responsive science education. Accessing Indigenous knowledge, the first stage of the empirical model, can therefore be understood as partly dependent on teachers' cultural and experiential repertoires.

However, beginning with familiar experience did not guarantee deep translation. The distinction between deep and illustrative cases shows that culturally familiar contexts can serve two different functions. They can operate as motivational hooks that precede conventional instruction, or they can become epistemic objects that students investigate and reason about. This difference is consistent with culturally responsive teaching perspectives that call for cultural knowledge to shape curriculum, communication, and intellectual participation rather than merely improve lesson attractiveness (Gay, 2018). When students investigated why a traditional structure, material, agricultural practice, or environmental observation worked as it did, local knowledge influenced the intellectual structure of the lesson. When the same knowledge appeared only in the introduction, the underlying structure of science instruction remained largely unchanged.

Indonesian research provides useful evidence that local culture can be transformed into substantive science-learning activities. Culturally responsive ethnochemistry has been connected with critical-thinking activities and cultural identity development in chemistry education (Rahmawati, Baeti, et al., 2019; Rahmawati, Ridwan, Rahman, et al., 2019). Culturally responsive transformative teaching has likewise been used to connect chemistry education with cultural sustainability and identity (Rahmawati et al., 2023). Inquiry integrated with ethnoscience has also been employed to make cultural phenomena part of students' reasoning processes rather than simply contextual examples (Verawati et al., 2022).

The present results extend these Indonesian studies by showing that movement from contextualization to inquiry depends on teacher decisions made before and during instruction. Local knowledge does not automatically become inquiry merely because it is available. Teachers must identify investigable dimensions, formulate appropriate questions, preserve relevant cultural context, and determine how scientific interpretation will be introduced. The implication is that local-to-scientific sequencing should not be evaluated merely by asking whether teaching begins with a familiar cultural example. A more consequential question is whether the local knowledge continues to influence what students observe, question, explain, compare, and evaluate after formal science enters the lesson.

The six-stage empirical model developed from this study synthesizes the translation process as accessing, selecting, interpreting, negotiating, transforming, and representing Indigenous knowledge. Its purpose is explanatory rather than prescriptive. The model does not imply that every teacher should follow six fixed steps in a predetermined order. The recursive patterns in the cases indicate that teachers can return to earlier decisions when later pedagogical or epistemic problems emerge.

The first theoretical contribution is the distinction between knowledge availability and instructional selection. Teachers encountered substantially more community knowledge than they ultimately used. Selection represented a separate decision shaped by curricular relevance, student familiarity, and perceived teachability. This helps explain why teachers may value Indigenous knowledge while nevertheless incorporating only particular dimensions of it.

The second contribution is the identification of epistemic negotiation as an intervening process between scientific interpretation and pedagogical transformation. The model suggests that teachers do not simply identify a science concept and immediately convert a cultural practice into an activity. They make decisions about epistemic boundaries before and during pedagogical transformation. These decisions affect what students eventually encounter as authoritative, comparable, contestable, or culturally distinct knowledge.

This dimension aligns with scholarship arguing that productive relations among knowledge systems require negotiation rather than assimilation. Tengö et al. (2014) emphasize the value of recognizing multiple evidence bases, while Tengö et al. (2017) explicitly identify translation and negotiation as key processes in weaving knowledge systems. Aikenhead and Michell (2011) similarly emphasize bridging Indigenous and scientific ways of knowing without treating the relationship as simple conversion. The Lombok model shows how comparable knowledge-system processes occur at the level of everyday teacher decision-making.

The third contribution is the separation of epistemic positioning from pedagogical depth. Earlier research has demonstrated that teachers adopt different approaches to Indigenous knowledge (Naidoo & Vithal, 2014). The present study adds that the epistemic stance adopted by a teacher does not necessarily predict how deeply Indigenous knowledge is transformed pedagogically. This makes it possible to analyze teacher practice along at least two dimensions rather than assigning each teacher a single integration category.

The fourth contribution concerns the nature of Indigenous knowledge itself. Treating Indigenous knowledge as something that moves through a translation process avoids conceptualizing it as a static set of culturally distinctive facts. Indigenous knowledge is relational, situated, and connected with practices, environments, and communities (Berkes, 2018; Whyte, 2013). The translation model therefore foregrounds transformation and boundary decisions rather than assuming that cultural knowledge can be transported into school unchanged.

This perspective is also compatible with critiques of a rigid Indigenous/scientific binary. Agrawal (1995) and Ogawa (1995) both challenge overly narrow assumptions about what counts as legitimate knowledge or science, albeit from different conceptual positions. The current findings suggest that teachers work precisely within this ambiguous space. Their practices involve both connecting and differentiating knowledge, sometimes within the same case.

Finally, the model provides a way of interpreting Indigenous knowledge integration without assuming that cultural inclusion is automatically epistemically equitable. School science retains considerable institutional authority through curriculum, textbooks, assessment, teacher preparation, and disciplinary expectations. The scientific-privileging cases make that asymmetry explicit, but a subtler asymmetry can also occur when cultural knowledge is included only after being translated into scientific terms. This concern is consistent with decolonizing perspectives in science education that caution against inclusion practices that ultimately assimilate Indigenous knowledge into dominant epistemological structures (Aikenhead & Elliott, 2010; Seehawer, 2018).

The contribution of the model is therefore not to propose an idealized fusion of knowledge systems. Instead, it provides analytical language for examining the decisions through which knowledge is selected, related, bounded, transformed, and represented. The findings move the discussion beyond the question of whether Indigenous knowledge should be integrated into science education. Existing scholarship already provides substantial justification for culturally grounded and epistemically plural science education (Bang & Medin, 2010; Snively & Corsiglia, 2001). The more specific contribution of this study is to demonstrate that such integration is produced through teacher translation work.

Science teachers in the Lombok cases functioned simultaneously as selectors of culturally relevant knowledge, interpreters of relationships with science, negotiators of epistemic boundaries, designers of pedagogical transformations, and representational agents in classroom interaction. Understanding these roles allows Indigenous knowledge integration to be assessed not simply by the visibility of cultural content but by the quality of the epistemic relationships and learning opportunities created when knowledge moves into classroom science.

CONCLUSION

This study examined how science teachers in Lombok translate Indigenous knowledge into classroom science and showed that this process involves considerably more than the inclusion of local examples in formal science instruction. Across the 15 teacher cases, translation emerged as an interconnected process of accessing, selecting, interpreting, negotiating, transforming, and representing Indigenous knowledge. Teachers first encountered culturally situated knowledge through family, community, local environments, cultural practices, and students' experiences. They then selected particular knowledge according to its familiarity and curricular relevance, interpreted its relationship with scientific concepts, negotiated differences between knowledge systems, transformed it pedagogically, and represented it through classroom interactions that generally moved from locally familiar experience toward scientific interpretation.

The findings further revealed meaningful variation in how this translation occurred. Three epistemic positions were identified: contextual bridging, epistemic restraint, and scientific privileging. These positions reflected different ways of managing relationships and differences between Indigenous and scientific knowledge. At the pedagogical level, the cases demonstrated deep translation, limited or illustrative translation, and mixed or discrepant translation. Importantly, these two dimensions did not correspond directly. A teacher could position school science as epistemically dominant while still transforming Indigenous knowledge into substantive inquiry, whereas another teacher could recognize Indigenous knowledge more openly but use it only as an introductory illustration. Epistemic positioning and pedagogical depth should therefore be understood as related but distinct dimensions of teacher practice.

The study consequently supports a shift from conceptualizing Indigenous knowledge use as simple integration toward understanding it as teacher-mediated translation. Science teachers functioned simultaneously as selectors of culturally relevant knowledge, interpreters of relationships across knowledge systems, negotiators of epistemic boundaries, designers of pedagogical transformations, and representational agents in classroom interaction. The empirical model developed from the study makes these forms of teacher work visible while recognizing that translation is recursive rather than strictly linear.

The principal contribution of the study is therefore not merely to demonstrate that Indigenous knowledge can be incorporated into science education. Rather, it explains how culturally situated knowledge changes as it moves from community contexts into formal classroom science and how teachers influence that movement. Meaningful inclusion cannot be assessed only by whether Indigenous knowledge appears in a lesson. It also requires attention to what knowledge is selected, how it is interpreted, whose explanations are granted epistemic authority, what cultural meanings are retained, what students are invited to investigate, and how relationships between knowledge systems are ultimately represented. In this sense, translating Indigenous knowledge into classroom science is simultaneously an epistemic, cultural, and pedagogical process.

LIMITATIONS

Several limitations should be considered when interpreting the findings. First, the study involved 15 purposively selected science teachers from West Lombok, Central Lombok, and East Lombok, so the resulting empirical model should be understood as analytically grounded in these cases rather than statistically representative of all science teachers or Indigenous knowledge contexts. Second, classroom observations were conducted only in seven of the 15 cases, meaning that evidence of enacted translation was stronger for the observed teachers than for the remaining participants, whose interpretations relied more heavily on interviews, instructional documents, and field memos. Third, the 26 instructional documents varied in type and coverage and represented selected teaching materials rather than complete records of each teacher's instructional practice, as illustrated by the discrepancy identified in T10 between reported and documented practice. Fourth, interviews were a major source for reconstructing teacher reasoning and may have been influenced by retrospective interpretation, memory, or socially desirable responses, although triangulation with documents and observations reduced this limitation. Finally, the study focused primarily on teachers as the unit of analysis and did not independently investigate students, parents, community knowledge holders, or other cultural actors; consequently, the study cannot determine whether classroom representations fully corresponded with how particular forms of Indigenous knowledge are understood, authorized, or valued within their originating communities.

RECOMMENDATIONS

The findings suggest that efforts to strengthen Indigenous knowledge in science education should move beyond providing teachers with lists of local examples and instead support the full translation process, including identifying culturally relevant knowledge, determining curricular relevance, interpreting its relationship with scientific concepts, negotiating epistemic differences, and transforming it into meaningful inquiry, analysis, comparison, and representation. Teacher professional development should therefore address both epistemic and pedagogical capacity, while schools and curriculum developers should distinguish cultural visibility from substantive pedagogical translation and provide opportunities for students to reason with Indigenous knowledge rather than encounter it only as an introductory context. Greater collaboration with community knowledge holders is also needed to improve cultural accuracy, clarify appropriate boundaries of representation, and avoid unnecessary reduction of culturally situated meanings into scientific terminology. Future research should test and refine the six-stage model across different cultural, disciplinary, and educational settings, employ longitudinal and repeated classroom observations to examine consistency between reported, planned, and enacted practice, and include students and community knowledge holders to investigate epistemic agency, cultural integrity, learning outcomes, and perceptions of representation. Intervention studies may also use the translation model as an analytical framework for designing and evaluating teacher professional development, while treating it as an explanatory tool rather than a fixed instructional procedure.

Author Contributions

The authors have sufficiently contributed to the study, and have read and agreed to the published version of the manuscript.

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Conflict of Interests

The authors declare no conflict of interest.

REFERENCES

Agrawal, A. (1995). Dismantling the divide between indigenous and scientific knowledge. *Development and Change, 26*(3), 413–439. https://doi.org/10.1111/j.1467-7660.1995.tb00560.x

Aikenhead, G. S. (1996). Science education: Border crossing into the subculture of science. *Studies in Science Education, 27*(1), 1–52. https://doi.org/10.1080/03057269608560077

Aikenhead, G. S., & Elliott, D. (2010). An emerging decolonizing science education in Canada. *Canadian Journal of Science, Mathematics and Technology Education, 10*(4), 321–338. https://doi.org/10.1080/14926156.2010.524967

Aikenhead, G. S., & Jegede, O. J. (1999). Cross-cultural science education: A cognitive explanation of a cultural phenomenon. *Journal of Research in Science Teaching, 36*(3), 269–287.

Aikenhead, G. S., & Michell, H. (2011). *Bridging cultures: Indigenous and scientific ways of knowing nature*. Pearson Canada.

Andreotti, V., Ahenakew, C., & Cooper, G. (2011). Epistemological pluralism: Ethical and pedagogical challenges in higher education. *AlterNative: An International Journal of Indigenous Peoples, 7*(1), 40–50. https://doi.org/10.1177/117718011100700104

Aronson, B., & Laughter, J. (2016). The theory and practice of culturally relevant education: A synthesis of research across content areas. *Review of Educational Research, 86*(1), 163–206. https://doi.org/10.3102/0034654315582066

Bang, M., & Medin, D. (2010). Cultural processes in science education: Supporting the navigation of multiple epistemologies. *Science Education, 94*(6), 1008–1026. https://doi.org/10.1002/sce.20392

Barnhardt, R., & Kawagley, A. O. (2005). Indigenous knowledge systems and Alaska Native ways of knowing. *Anthropology & Education Quarterly, 36*(1), 8–23. https://doi.org/10.1525/aeq.2005.36.1.008

Bartlett, C., Marshall, M., & Marshall, A. (2012). Two-Eyed Seeing and other lessons learned within a co-learning journey of bringing together Indigenous and mainstream knowledges and ways of knowing. *Journal of Environmental Studies and Sciences, 2*(4), 331–340. https://doi.org/10.1007/s13412-012-0086-8

Barton, A. C., & Tan, E. (2009). Funds of knowledge and discourses and hybrid space. *Journal of Research in Science Teaching, 46*(1), 50–73. https://doi.org/10.1002/tea.20269

Berkes, F. (2018). *Sacred ecology* (4th ed.). Routledge.

Brown, J. C., & Crippen, K. J. (2016). Designing for culturally responsive science education through professional development. *International Journal of Science Education, 38*(3), 470–492. https://doi.org/10.1080/09500693.2015.1136756

Brown, J. C., & Crippen, K. J. (2017). The knowledge and practices of high school science teachers in pursuit of cultural responsiveness. *Science Education, 101*(1), 99–133. https://doi.org/10.1002/sce.21250

Costa, V. B. (1995). When science is “another world”: Relationships between worlds of family, friends, school, and science. *Science Education, 79*(3), 313–333. https://doi.org/10.1002/sce.3730790306

Gay, G. (2018). *Culturally responsive teaching: Theory, research, and practice* (3rd ed.). Teachers College Press.

Jegede, O. J. (1995). Collateral learning and the eco-cultural paradigm in science and mathematics education in Africa. *Studies in Science Education, 25*(1), 97–137. https://doi.org/10.1080/03057269508560051

Ladson-Billings, G. (1995). Toward a theory of culturally relevant pedagogy. *American Educational Research Journal, 32*(3), 465–491. https://doi.org/10.3102/00028312032003465

Latip, A., Hernani, & Kadarohman, A. (2024). Local and indigenous knowledge (LIK) in science learning: A systematic literature review. *Journal of Turkish Science Education, 21*(4), 651–667. https://doi.org/10.36681/tused.2024.035

Lee, H., Yen, C.-F., & Aikenhead, G. S. (2012). Indigenous elementary students' science instruction in Taiwan: Indigenous knowledge and Western science. *Research in Science Education, 42*, 1183–1199. https://doi.org/10.1007/s11165-011-9240-7

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

Maddock, M. N. (1981). Science education: An anthropological viewpoint. *Studies in Science Education, 8*(1), 1–26. https://doi.org/10.1080/03057268108559884

Mazzocchi, F. (2006). Western science and traditional knowledge: Despite their variations, different forms of knowledge can learn from each other. *EMBO Reports, 7*(5), 463–466. https://doi.org/10.1038/sj.embor.7400693

Miles, M. B., Huberman, A. M., & Saldaña, J. (2020). *Qualitative data analysis: A methods sourcebook* (4th ed.). SAGE.

Mkhwebane, L. N. (2024). Life sciences teachers' integration of indigenous knowledge: A vision for making science classrooms culturally responsive. *Eurasia Journal of Mathematics, Science and Technology Education, 20*(8), em2483. https://doi.org/10.29333/ejmste/14859

Mlotshwa, N., & Tsakeni, M. (2024). Challenges experienced by teachers when integrating indigenous knowledge systems in natural sciences practical work. *African Journal of Research in Mathematics, Science and Technology Education, 28*(2), 300–313. https://doi.org/10.1080/18117295.2024.2414160

Moll, L. C., Amanti, C., Neff, D., & Gonzalez, N. (1992). Funds of knowledge for teaching: Using a qualitative approach to connect homes and classrooms. *Theory Into Practice, 31*(2), 132–141. https://doi.org/10.1080/00405849209543534

Naidoo, P. D., & Vithal, R. (2014). Teacher approaches to introducing indigenous knowledge in school science classrooms. *African Journal of Research in Mathematics, Science and Technology Education, 18*(3), 253–263. https://doi.org/10.1080/10288457.2014.956407

Nakata, M. (2007). The cultural interface. *The Australian Journal of Indigenous Education, 36*(S1), 7–14. https://doi.org/10.1017/S1326011100004646

Ogawa, M. (1995). Science education in a multiscience perspective. *Science Education, 79*(5), 583–593. https://doi.org/10.1002/sce.3730790507

Ogegbo, A. A., & Ramnarain, U. (2024). A systematic review of pedagogical practices for integrating indigenous knowledge systems in science teaching. *African Journal of Research in Mathematics, Science and Technology Education, 28*(3), 343–361. https://doi.org/10.1080/18117295.2024.2374133

Ogunniyi, M. B. (2007a). Teachers' stances and practical arguments regarding a science-indigenous knowledge curriculum: Part 1. *International Journal of Science Education, 29*(8), 963–986. https://doi.org/10.1080/09500690600931020

Ogunniyi, M. B. (2007b). Teachers' stances and practical arguments regarding a science-indigenous knowledge curriculum: Part 2. *International Journal of Science Education, 29*(10), 1189–1207. https://doi.org/10.1080/09500690600931038

Ogunniyi, M. B., & Iwuanyanwu, P. N. (2024). Analysis of teachers' perspectives towards the use of IKS to improve STEM education for sustainable development. *African Journal of Research in Mathematics, Science and Technology Education, 28*(3), 319–329. https://doi.org/10.1080/18117295.2024.2352980

Park, S., & Oliver, J. S. (2008). Revisiting the conceptualisation of pedagogical content knowledge (PCK): PCK as a conceptual tool to understand teachers as professionals. *Research in Science Education, 38*(3), 261–284. https://doi.org/10.1007/s11165-007-9049-6

Rahmawati, Y., Baeti, H. R., Ridwan, A., Suhartono, S., & Rafiuddin, R. (2019). A culturally responsive teaching approach and ethnochemistry integration of Tegal culture for developing chemistry students' critical thinking skills in acid-based learning. *Journal of Physics: Conference Series, 1402*, 055050. https://doi.org/10.1088/1742-6596/1402/5/055050

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

Rahmawati, Y., Ridwan, A., Rahman, A., & Kurniadewi, F. (2019). Chemistry students' identity empowerment through ethnochemistry in culturally responsive transformative teaching (CRTT). *Journal of Physics: Conference Series, 1156*, 012032. https://doi.org/10.1088/1742-6596/1156/1/012032

Ramdiah, S., Abidinsyah, A., Royani, M., Husamah, H., & Fauzi, A. (2020). South Kalimantan local wisdom-based biology learning model. *European Journal of Educational Research, 9*(2), 639–653. https://doi.org/10.12973/eu-jer.9.2.639

Saldaña, J. (2021). *The coding manual for qualitative researchers* (4th ed.). SAGE.

Sealy, M., Lee Bae, C., & Hogan, E. (2026). Integrating students' and teachers' funds of knowledge through culturally responsive and relevant science education. *Cultural Studies of Science Education*. Advance online publication. https://doi.org/10.1007/s11422-026-10287-5

Seehawer, M. (2018). South African science teachers' strategies for integrating Indigenous and Western knowledges in their classes: Practical lessons in decolonisation. *Educational Research for Social Change, 7*(Special Issue), 91–110. https://doi.org/10.17159/2221-4070/2018/v7i0a7

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4–14. https://doi.org/10.3102/0013189X015002004

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1–23. https://doi.org/10.17763/haer.57.1.j463w79r56455411

Smith, T., Avraamidou, L., & Adams, J. D. (2022). Culturally relevant/responsive and sustaining pedagogies in science education: Theoretical perspectives and curriculum implications. *Cultural Studies of Science Education, 17*, 637–660. https://doi.org/10.1007/s11422-021-10082-4

Snively, G., & Corsiglia, J. (2001). Discovering Indigenous science: Implications for science education. *Science Education, 85*(1), 6–34. https://doi.org/10.1002/1098-237X%28200101%2985%3A1%3C6%3A%3AAID-SCE3%3E3.0.CO%3B2-R

Stake, R. E. (2006). *Multiple case study analysis*. Guilford Press.

Suprapto, N., Prahani, B. K., & Cheng, T. H. (2021). Indonesian curriculum reform in policy and local wisdom: Perspectives from science education. *Jurnal Pendidikan IPA Indonesia, 10*(1), 69–80. https://doi.org/10.15294/jpii.v10i1.28438

Tengö, M., Brondizio, E. S., Elmqvist, T., Malmer, P., & Spierenburg, M. (2014). Connecting diverse knowledge systems for enhanced ecosystem governance: The multiple evidence base approach. *Ambio, 43*, 579–591. https://doi.org/10.1007/s13280-014-0501-3

Tengö, M., Hill, R., Malmer, P., Raymond, C. M., Spierenburg, M., Danielsen, F., Elmqvist, T., & Folke, C. (2017). Weaving knowledge systems in IPBES, CBD and beyond: Lessons learned for sustainability. *Current Opinion in Environmental Sustainability, 26–27*, 17–25. https://doi.org/10.1016/j.cosust.2016.12.005

Tracy, S. J. (2010). Qualitative quality: Eight "big-tent" criteria for excellent qualitative research. *Qualitative Inquiry, 16*(10), 837–851. https://doi.org/10.1177/1077800410383121

van Driel, J. H., Verloop, N., & de Vos, W. (1998). Developing science teachers' pedagogical content knowledge. *Journal of Research in Science Teaching, 35*(6), 673–695.

Verawati, N. N. S. P., Harjono, A., Wahyudi, W., & Gummah, S. (2022). Inquiry-creative learning integrated with ethnoscience: Efforts to encourage prospective science teachers' critical thinking in Indonesia. *International Journal of Learning, Teaching and Educational Research, 21*(9), 232–248. https://doi.org/10.26803/ijlter.21.9.13

Wahyudiati, D. (2022). Ethnochemistry: Exploring the potential of Sasak and Java local wisdom as a teaching materials. *Jurnal Pendidikan Kimia Indonesia, 6*(2), 116–122. https://doi.org/10.23887/jpki.v6i2.49890

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

Warren, B., Ballenger, C., Ogonowski, M., Rosebery, A. S., & Hudicourt-Barnes, J. (2001). Rethinking diversity in learning science: The logic of everyday sense-making. *Journal of Research in Science Teaching*, *38*(5), 529–552. https://doi.org/10.1002/tea.1017

Whyte, K. P. (2013). On the role of traditional ecological knowledge as a collaborative concept: A philosophical study. *Ecological Processes, 2*, Article 7. https://doi.org/10.1186/2192-1709-2-7

Yin, R. K. (2018). *Case study research and applications: Design and methods* (6th ed.). SAGE.