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Integrating Local Community Ethnobiological Knowledge into Senior High School Biology Teaching Modules: A Systematic Review (2021–2026)

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ABSTRACT
Local community ethnobiological knowledge, encompassing ethnobotany, ethnozoology, and ethnoecology, offers a rich and culturally grounded resource for contextualizing senior high school biology instruction, yet its systematic contribution to teaching module development remains dispersed across a rapidly growing but fragmented body of literature. This article presents a systematic review, informed by PRISMA-style identification, screening, eligibility, and inclusion procedures, of studies published between 2021-2026 examining how local ethnobiological knowledge has been mapped onto biology curriculum content, translated into validated teaching modules, and evaluated for classroom effectiveness. Twenty-two sources met the inclusion criteria, spanning Indonesian regional case studies, international comparative evidence, and methodological and needs-analysis literature. The review finds that ethnobiological knowledge is most frequently mapped onto biodiversity, classification, and ecosystem content, and that resulting modules consistently achieve high expert-validation scores (validity coefficients as high as 1.00) and produce meaningful learning gains, with normalized gain (N-Gain) scores ranging from moderate (0.42) to high (0.83) and comparative quasi-experimental evidence showing ethnobiology-based instruction outperforming lecture-based and peer-tutoring approaches. Despite this effectiveness, the review identifies persistent gaps: available teaching materials remain limited and unevenly distributed across biology topics, teachers report insufficient training and frameworks for translating ecological knowledge into scientific content, community involvement in formal ethnobiology-based learning remains low, and student perspectives are markedly underrepresented in the design literature. The review concludes with recommendations for systematic teacher training, broader topic coverage beyond biodiversity, and stronger integration of student and community voices in future module development.

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INTRODUCTION

Biology education is most effective when abstract scientific concepts are anchored in contexts that are meaningful and familiar to learners. In culturally diverse settings, local community knowledge systems can provide a natural bridge between students' everyday experiences and formal scientific concepts. Local community ethnobiological knowledge, comprising ethnobotany (knowledge of plant use), ethnozoology (knowledge of animal use), and ethnoecology (knowledge of ecological relationships and management), represents an especially rich source of such context. These knowledge systems connect biological concepts with culturally transmitted practices that students may already encounter in their daily lives. For example, traditional knowledge of medicinal plants such as turmeric (*Curcuma longa*), betel leaf (*Piper betle*), and cat's whiskers (*Orthosiphon aristatus*) can illustrate concepts related to biodiversity, classification, and biochemical properties that align with senior high school biology curriculum content (Mursalin et al., 2025).

Translating local community ethnobiological knowledge into teaching modules is conceptually and pedagogically supported by the broader ethnoscience approach, which recognizes local and Indigenous knowledge as legitimate starting points for scientific inquiry rather than knowledge to be replaced by formal science. In this review, ethnoscience refers to approaches that intentionally integrate local or Indigenous knowledge with formal school science to enhance learning relevance, conceptual understanding, and cultural continuity. Ethnoscience-based approaches have been shown to support science literacy by connecting scientific concepts and processes with contexts that students encounter in their everyday lives (Ikram et al., 2022). Systematic reviews of local wisdom and sustainability research indicate that integrating local knowledge into formal science education has become an increasingly important focus in contemporary Indonesian and international scholarship (Lestari et al., 2024). More focused systematic reviews of ethnoscience in science learning likewise report a consistent trend toward incorporating local cultural knowledge into formal science curricula, particularly in biology and environmental education (Sari et al., 2023).

Despite this growing scholarly interest, the specific pathway from ethnobiological knowledge documented within local communities to validated, classroom-ready senior high school biology teaching modules remains only partially mapped. There is currently no systematic overview of how local community ethnobiological knowledge has been mapped onto senior high school biology curriculum content, translated into validated teaching modules, and evaluated for classroom effectiveness. Existing studies tend to be fragmented by geographical context (e.g., Dayak, Baduy, Toraja, and East Nusa Tenggara) or by specific forms of ethnobiological knowledge, such as medicinal plants, traditional food, and forest ethnobotany. This fragmentation makes it difficult to determine which biology topics have received the greatest attention, which remain underrepresented, and whether consistent patterns of effectiveness and implementation challenges emerge across different contexts. Needs-analysis studies conducted prior to module development, such as investigations into biology learning strategy course requirements (Islamiyati et al., 2021), further highlight the importance of systematically synthesizing existing evidence to inform the design and development of future teaching modules.

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This review therefore aims to: (a) systematically map how local ethnobiological knowledge has been translated into senior high school biology curriculum content; (b) synthesize the reported validity and classroom effectiveness of the resulting teaching modules; (c) identify the biology topics and geographical or cultural contexts that dominate the current literature, as well as those that remain underexplored; and (d) synthesize documented gaps, challenges, and recommendations for future module development.

METHODS

This study employed a systematic literature review (SLR) design guided by the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework. The review followed four main stages: identification, screening, eligibility assessment, and inclusion. The review aimed to systematically identify and synthesize studies examining the integration of local community ethnobiological knowledge into senior high school biology teaching modules, particularly studies addressing curriculum mapping, module development and validation, and classroom learning effectiveness. The PRISMA 2020 flow diagram summarizing the article identification and selection process is presented.

1. Identification

The literature search was conducted using four information sources: Google Scholar, GARUDA, SINTA, and Scopus. The final search was conducted in May 2026, and the search was restricted to publications from 2021 to 2026. A total of 142 records were identified, comprising 50 records from Google Scholar, 40 records from GARUDA, 30 records from SINTA, and 22 records from Scopus.

The search strategy used combinations of keywords related to local community ethnobiological knowledge, ethnoscience, biology education, and teaching modules. The main search terms included “ethnobiology,” “ethnoscience,” “ethnobotany,” “local wisdom,” “local knowledge,” “biology teaching module,” “biology teaching materials,” “modul ajar biologi,” “modul pembelajaran biologi,” “senior high school,” and “SMA.” Boolean operators AND and OR were used to combine related terms. The principal search string was: (“ethnobiology” OR “ethnoscience” OR “ethnobotany” OR “local wisdom” OR “local knowledge”) AND (“biology teaching module” OR “biology teaching materials” OR “modul ajar biologi” OR “modul pembelajaran biologi”) AND (“senior high school” OR “SMA”). Additional keyword combinations were applied when necessary to accommodate differences in terminology across the four information sources.

The identified records were compiled and checked for duplicate records before title and abstract screening. The resulting selection process was conducted according to the predefined inclusion and exclusion criteria and is summarized in the PRISMA 2020 flow diagram presented.

2. Screening and Eligibility

A total of 142 identified records were compiled for screening. After 34 duplicate records were removed, 108 records remained for title and abstract screening. At this stage, 68 records were excluded because they did not meet the predefined relevance criteria. The remaining 40 articles were retrieved in full text and assessed for eligibility.

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Studies were included if they met the following criteria: (a) they were published between 2021 and 2026 in a peer-reviewed journal, conference proceedings, or other recognized academic publication; (b) they empirically or conceptually examined the mapping, development, validation, or classroom implementation of teaching modules or other teaching materials grounded in local community ethnobiological knowledge, including ethnobotanical, ethnozoological, or ethnoecological knowledge; and (c) they focused on senior high school biology or science education or provided evidence that was directly transferable to this educational context. Studies conducted at closely related educational levels or in geographically comparable contexts were considered only when their findings provided clear and relevant implications for senior high school biology teaching.

Studies were excluded if they (a) focused exclusively on local wisdom or ethnoscience in non-science subject areas, such as language or social studies education, without transferable implications for biology; (b) did not substantially address local community ethnobiological knowledge; (c) did not examine teaching modules, teaching materials, curriculum mapping, validation, or classroom implementation; or (d) did not provide sufficient information relevant to the objectives of this review.

The screening and eligibility assessment were conducted by one reviewer. Titles and abstracts were screened first, followed by full-text assessment of potentially eligible studies. Of the 40 full-text articles assessed for eligibility, 18 were excluded based on the predefined exclusion criteria. The remaining 22 studies met all inclusion criteria and were included in the final systematic review. The article selection process therefore comprised 142 records identified, 34 duplicate records removed, 108 records screened, 68 records excluded during title and abstract screening, 40 full-text articles assessed for eligibility, 18 full-text articles excluded, and 22 studies included in the final synthesis. The complete selection process is presented in the PRISMA 2020 flow diagram (Figure 1).

3. Data Extraction and Synthesis

A standardized data extraction form was used to systematically record information from each of the 22 included studies. The extraction form included fields for authorship and publication year, geographical and cultural context, type of local community ethnobiological knowledge addressed, biology topic or curriculum content, educational level, type and characteristics of the teaching module or teaching material developed, research design, validation procedures, learning outcomes, and key quantitative or qualitative findings. Where reported, quantitative outcomes, including validity coefficients, percentage-based outcomes, normalized gain (N-Gain) scores, and comparative learning outcomes, were also extracted.

Data extraction was conducted by one reviewer using the standardized extraction form. Each extracted record was checked against the corresponding full-text article to minimize transcription and interpretation errors. When information was unclear or not reported in the original article, it was recorded as not reported rather than estimated or statistically imputed.

The extracted data were synthesized narratively and organized thematically into three main areas: (a) the mapping of local community ethnobiological knowledge onto senior high school biology curriculum content; (b) the development, validation, and classroom effectiveness of

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ethnobiology-based teaching modules; and (c) implementation gaps and challenges, including limitations in teacher preparation, topic coverage, community involvement, and student participation.

Because the 22 included studies varied substantially in research design, geographical and cultural context, biology topics, intervention characteristics, and outcome measures, statistical pooling of effect sizes was not considered appropriate. Therefore, no formal meta-analysis was conducted. Instead, the review synthesized the direction, range, and recurring patterns of findings across the included studies. Quantitative findings, such as validity scores and N-Gain values, were reported descriptively where available, while qualitative findings were organized according to the predefined thematic categories.

RESULTS

Twenty-two sources published between 2021 and 2026 met the inclusion criteria, comprising regional case studies, module development and validation studies, quasi-experimental intervention studies, needs-analysis papers, and systematic or narrative literature reviews, drawn predominantly from Indonesian contexts with supporting comparative evidence from Nigeria and Mexico.

1. Mapping of Ethnobiological Knowledge onto Biology Curriculum Content

Local ethnobiological practices can be systematically mapped onto senior high school biology curriculum content, particularly the topics of biodiversity, classification of living organisms, and ecosystems (Mursalin et al., 2025; Husni & Mukra, 2025). Table 1 summarizes seven regional or community contexts identified in the reviewed literature, together with the type of ethnobiological knowledge documented and the biology content area into which it has been integrated.

Table 1. Regional Mapping of Ethnobiological Knowledge into Biology Curriculum Content

Region / Community	Type of Ethnobiological Knowledge	Integrated Biology Content
Mulyoharjo, Central Java	Traditional medicinal plants	Biodiversity, classification, ecosystems (Mursalin et al., 2025)
Dayak, Central Kalimantan	Ethnobotany of forest plants	Biodiversity, biology practicum (Muhammad et al., 2026)
Baduy, Banten	Cultural ecosystem values	Ecosystem material, Pancasila Student Profile (Haka et al., 2024)
East Nusa Tenggara (NTT)	Traditional food knowledge	Biodiversity (Tpoenifu et al., 2023)
Toraja	Local potential and local wisdom	Contextual biology (multiple topics) (Sura et al., 2026)
Lombok (Karang Sidemen)	Ethnobotany of medicinal plants	Biodiversity teaching material (Putri et al., 2025)
Lombok (Sekotong region)	Ethnobotany, e-module development	Biodiversity, student motivation and outcomes (Rofi'i et al., 2022)

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A field study in Karang Sidemen Village identified 45 medicinal plant species from 19 families that could be directly incorporated as biodiversity teaching material (Putri et al., 2025), illustrating the scale of ethnobotanical detail available for curriculum translation from a single community. Complementing this village-level detail, a related development study in the wider Lombok region translated local ethnobotanical knowledge into a validated e-module explicitly designed to strengthen student motivation and learning outcomes, demonstrating that ethnobiological mapping can extend beyond content alignment to encompass motivational and affective learning goals (Rofi'i et al., 2022).

Despite this demonstrated richness, previous systematic evidence indicates that the coverage of ethnoscience within biology education remains uneven across topics and educational applications. A systematic literature review conducted by Husni and Mukra (2025), covering studies published between 2021 and 2025, reported that 36.7% of the reviewed studies focused on the development of ethnoscience-based learning tools and 33.3% on classroom implementation. The same review found that biodiversity was the most frequently represented biology topic linked to local wisdom (29% of studies), whereas biotechnology, the digestive system, and body temperature regulation each accounted for approximately 3% of studies. These findings are cited here as evidence from the previous review rather than as original calculations from the 22 studies included in the present review. They nevertheless highlight a potential gap between the breadth of ethnobiological knowledge available in local communities and its translation into biology-topic-specific teaching materials beyond biodiversity and ecosystem content.

2. Validity and Classroom Effectiveness of Ethnobiology-Based Modules

Teaching modules developed from ethnobiological knowledge consistently demonstrate high validity and measurable classroom effectiveness. Table 2 summarizes six studies reporting quantitative validity or effectiveness outcomes.

Table 2. Validity and Effectiveness Outcomes of Ethnobiology-Based Teaching Modules

Study	Module / Intervention	Key Outcome
Muhammad et al. (2026)	Dayak ethnobotany-based module	Validity score = 1.00 (very high); N-Gain = 0.83 (high, cognitive)
Haka et al. (2024)	Baduy local wisdom e-module	90% content accuracy; 83% positive student response
Tpoenifu et al. (2023)	NTT traditional food biodiversity module	"Very feasible" validation; 88.8% student response
Ajayi et al. (2023)	Ethnobiology-based instruction (Nigeria)	Students receiving ethnobiology-based instruction achieved significantly better learning outcomes than those in the lecture and peer-tutoring groups; numerical effect estimates were not reported in the present synthesis.
Rahmat et al. (2026)	Socio-ecological ethnobiology approach	Mean N-Gain = 0.42 (moderate, environmental knowledge)

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Study	Module / Intervention	Key Outcome
Sriyati et al. (2025)	Teacher ethnoscience module training	93.5% of teachers able to design modules; 100% agreement on conceptual/character benefit

Across the studies summarized in Table 2, ethnobiology-based modules achieve consistently high expert-validity ratings, ranging from "very feasible" classifications to a near-maximal validity coefficient of 1.00 (Muhammad et al., 2026), alongside high rates of positive student reception, reported at 83% to 88.8% across two independently validated modules (Haka et al., 2024; Tpoenifu et al., 2023). Learning gains, measured through normalized gain (N-Gain) statistics, range from moderate (0.42) to high (0.83), suggesting that the magnitude of cognitive benefit may vary depending on module design, content area, and implementation context rather than reflecting a uniform effect of ethnobiological integration per se (Muhammad et al., 2026; Rahmat et al., 2026).

Comparative quasi-experimental evidence beyond the Indonesian context reinforces these findings: a quasi-experimental study in Ogun State, Nigeria, found that senior secondary biology students taught using ethnobiology-based instruction outperformed peers taught through lecture-based and peer-tutoring methods (Ajayi et al., 2023), suggesting that the pedagogical benefit of ethnobiological integration may generalize beyond the Indonesian archipelago to other culturally rich, biodiversity-abundant national contexts. Complementing this classroom-level evidence, a broader ethnoscience-based biology learning study found measurable improvements in both students' environmental awareness and scientific literacy (Ikram et al., 2022), indicating that the benefits of ethnobiological integration extend beyond content-knowledge gains to encompass affective and literacy-related outcomes as well.

Beyond direct classroom outcomes, ethnobiology-based learning is also associated with strengthened conservation awareness and character values. A culturally responsive digital pedagogy study integrating ethnomycology (fungal ethnobiology) found that the approach fostered both scientific literacy and conservation awareness among senior high school students (Wibawanti et al., 2025), while a socio-ecological ethnobiology approach implemented with biology education students produced measurable increases in environmental conservation awareness, alongside a reported 34.7% increase in positive attitudes toward the environment among learners in West Java (Rahmat et al., 2026).

3. Teacher Capacity and Training Outcomes

Teacher training in ethnoscience-based module design has demonstrated strong effectiveness where implemented. A structured training program found that 93.5% of participating biology teachers were able to independently design ethnoscience-based modules following the intervention, and 100% agreed that integrating local wisdom improved both students' conceptual understanding and character values (Sriyati et al., 2025). This finding is particularly notable given that, absent such training, teachers commonly report insufficient frameworks for translating local ecological knowledge into scientifically structured learning material (Amri et al., 2025; Flores-Silva et al., 2024).

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The near-universal success rate reported by trained teachers stands in contrast to the broader implementation literature, which more commonly documents teacher readiness and capacity as a persistent barrier rather than a solved problem (see Section 3.4), suggesting that structured, intensive training interventions may be capable of substantially closing the ethnoscience-translation gap identified elsewhere in the literature, though this evidence currently derives from a single training study and would benefit from replication across broader teacher populations.

4. Gaps and Implementation Challenges

Despite demonstrated effectiveness, the reviewed literature identifies several persistent gaps and challenges. Available teaching materials remain limited in scope and have not yet systematically optimized local cultural values across the full range of biology topics (Sura et al., 2026; Sofiyana et al., 2026). Teachers frequently lack the training and structured frameworks needed to translate local ecological knowledge into scientifically valid learning resources (Amri et al., 2025; Flores-Silva et al., 2024), a pattern consistent with international evidence from rural Mexican schools, where ethnobotany-based science teaching required considerable teacher scaffolding to be implemented effectively (Flores-Silva et al., 2024).

Community involvement in formal ethnobiology-based learning remains comparatively low, even in contexts where the ecological and cultural potential of the surrounding community environment has already been identified by researchers (Wibawanti et al., 2025). Perhaps most notably for future research and design, studies incorporating student perspectives remain minimal, accounting for only approximately 3.3% of the reviewed research base, meaning that module development has been driven predominantly by developer and researcher viewpoints rather than end-user student input (Husni & Mukra, 2025).

These implementation challenges are compounded by module development processes that, while methodologically well established through models such as Research and Development (R&D), ADDIE, and Borg and Gall, do not by default incorporate systematic needs analysis of the specific biology topics, student populations, and teacher readiness levels relevant to a given context. Needs-analysis studies conducted in advance of module development, such as an investigation into the requirements of a biology learning strategy course (Islamiyati et al., 2021), illustrate a methodologically stronger alternative pathway that more directly grounds module design in documented classroom and learner needs before development begins, though such needs-analysis-first approaches remain a minority practice within the broader ethnobiology-based module literature.

DISCUSSION

The synthesis of the 22 included studies indicates that local community ethnobiological knowledge can serve as a valuable contextual resource for developing senior high school biology teaching modules. In the present review, the strongest evidence was concentrated in studies reporting module validity, student responses, and learning gains. For example, Muhammad et al. (2026) reported a validity score of 1.00 and an N-Gain of 0.83, while Haka et al. (2024) and Tpoenifu et al. (2023) reported high levels of content feasibility and positive student responses.

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These findings suggest that ethnobiological knowledge can be successfully translated into formal teaching modules when the content is systematically aligned with biology curriculum objectives. However, the heterogeneity of study designs, instruments, and outcome measures means that these results should be interpreted as evidence of promising educational value rather than as evidence that ethnobiology-based modules are universally superior to conventional instruction.

The finding from Ajayi et al. (2023), which reported better learning outcomes for ethnobiology-based instruction than for lecture and peer-tutoring groups, provides additional comparative support for the potential effectiveness of contextualized ethnobiology-based learning. Nevertheless, this evidence comes from a single international study and from a different educational and cultural context. Therefore, the present review does not support broad claims of cross-cultural generalizability. Rather, the convergence between the Indonesian studies and the Nigerian evidence suggests that connecting biological concepts with culturally familiar knowledge may be a potentially transferable instructional principle that requires further testing across different educational settings.

The evidence also indicates that the scope of ethnobiology-based biology teaching remains uneven across curriculum topics. Previous systematic evidence from Husni and Mukra (2025) identified biodiversity as the most frequently represented topic and reported substantially lower representation for areas such as biotechnology, the digestive system, and body temperature regulation. These percentages are findings from the previous review and were not recalculated from the 22 studies included in the present review. When considered alongside the present synthesis, they suggest that ethnobiology-based teaching has been more readily developed for topics with an obvious connection to plants, animals, biodiversity, and ecosystems. By contrast, topics involving molecular, physiological, or technological processes may require more deliberate conceptual translation between local knowledge and formal biology.

This pattern supports a topic-first approach to module development. For example, rather than beginning with a documented local medicinal-plant practice and subsequently identifying a suitable biology topic, researchers could begin with an underrepresented topic such as human physiology and then investigate whether local knowledge concerning traditional health practices, nutrition, body functions, or environmental adaptation can provide scientifically appropriate contextual examples. Such an approach could broaden the range of curriculum content addressed by ethnobiology-based teaching while maintaining alignment with formal scientific concepts. Importantly, local knowledge should be used as a contextual and inquiry-based resource rather than treated as automatically equivalent to scientifically established explanations.

Teacher capacity represents another important implementation issue. Sriyati et al. (2025) reported that 93.5% of participating teachers were able to design ethnoscience-based modules following training, with all participants reporting agreement regarding conceptual and character-related benefits. This finding indicates that structured professional development may strengthen teachers' ability to translate local knowledge into instructional materials. However, because the evidence comes from a single teacher-training study, it is premature to conclude that teacher capacity is generally a highly trainable competency across contexts. Instead, the finding provides preliminary evidence that targeted training may help address an implementation barrier identified in other studies (Amri et al., 2025; Flores-Silva et al., 2024). Future studies should therefore

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examine whether similar training outcomes can be replicated with larger and more diverse teacher populations.

The limited attention given to student and community perspectives also emerges as an important issue. The 22-study synthesis included studies reporting student responses to completed modules, but positive response rates should not automatically be interpreted as evidence that students participated in the earlier stages of module design. Similarly, evidence of community involvement was limited in the reviewed literature, including the concerns identified by Wibawanti et al. (2025). Thus, students and local communities appear to remain less involved in the formative stages of ethnobiology-based module development than researchers, teachers, or curriculum experts. This distinction is important because ethnobiological knowledge is socially and culturally situated. Greater involvement of students and knowledge-holding communities could improve contextual relevance, cultural accuracy, and the appropriateness of how local knowledge is represented in formal biology education.

Overall, the findings of this review suggest that the contribution of local community ethnobiological knowledge is strongest when three elements are connected: culturally grounded knowledge, explicit alignment with biology curriculum objectives, and systematic instructional development and evaluation. The evidence does not establish that ethnobiology-based modules are inherently more effective than conventional materials in all settings. Rather, it indicates that they offer a promising contextualization strategy whose effectiveness depends on appropriate content selection, teacher preparation, curriculum alignment, and meaningful engagement with the communities and learners connected to the knowledge.

1. Implications for Practice

The findings of the present review suggest several practical priorities for biology curriculum developers, teachers, and teacher-training institutions:

Conduct needs analyses before module development. Needs analyses can identify underrepresented biology topics and determine which topics may benefit from local ethnobiological contextualization, building on approaches such as those reported by Islamiyati et al. (2021).

Adopt a topic-first development strategy. Developers should begin with underrepresented curriculum areas, such as biotechnology or human physiology, and then systematically identify relevant local ethnobiological knowledge instead of relying primarily on biodiversity- and ecosystem-related examples.

Strengthen teacher professional development. Structured training should provide teachers with practical guidance on identifying local knowledge, evaluating its scientific relevance, aligning it with curriculum competencies, and translating it into teaching modules. The outcomes reported by Sriyati et al. (2025) provide an initial basis for this approach, although replication is needed.

Increase student participation during development. Students should not be involved only through post-implementation response surveys. Their prior knowledge, learning needs, cultural experiences, and interpretations of local ethnobiological knowledge can be incorporated during the needs-analysis and prototype-development stages.

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Strengthen community participation. Local knowledge holders and community members should be consulted during content identification and validation to improve cultural accuracy and avoid decontextualizing or oversimplifying culturally transmitted knowledge.

2. Limitations of the Reviewed Literature

Several limitations characterize the evidence base synthesized in this review. First, the included literature was dominated by Indonesian regional studies, with relatively limited international comparative evidence. This distribution restricts the extent to which the effectiveness of ethnobiology-based teaching modules can be generalized across different cultural and educational contexts. Second, many studies used small-scale or single-region research and development designs, and relatively few reported long-term follow-up. Consequently, the durability of reported learning gains, student responses, and module effectiveness remains uncertain.

Third, the studies used heterogeneous instruments and outcome indicators, including validity coefficients, percentage-based feasibility or response measures, N-Gain scores, and comparative learning outcomes. These differences prevented direct quantitative comparison and formal effect-size pooling. Fourth, student and community participation in the formative stages of module development was insufficiently reported across the reviewed literature. Although several studies measured student responses after implementation, this should not be equated with meaningful participation in module design.

The present review also has methodological limitations. The search was conducted across Google Scholar, GARUDA, SINTA, and Scopus and was restricted to publications from 2021 to 2026. Consequently, relevant studies that were not indexed in these sources may have been missed. The review also depended on the language and accessibility of publications retrieved through the selected databases; therefore, relevant evidence published in less accessible sources or languages may not have been captured. In addition, publication bias cannot be ruled out because studies reporting successful module development or positive learning outcomes may be more likely to be published than studies reporting limited or null effects. Finally, data extraction and synthesis were conducted by a single reviewer. Although extracted information was checked against the corresponding full texts, the absence of independent duplicate screening and extraction may have introduced reviewer-related selection or interpretation bias.

3. Directions for Future Research

Future research should prioritize topic-first module development for biology areas that remain underrepresented in the ethnobiology education literature. For example, researchers could begin with a specific topic such as human physiology or biotechnology and systematically investigate local practices, ecological knowledge, traditional health practices, or locally relevant biological phenomena that can be connected to the formal curriculum. Such studies should explicitly document how local knowledge is transformed into scientifically accurate learning activities rather than simply adding cultural examples to existing materials.

Larger, multi-region studies are also needed to evaluate whether the promising outcomes reported by Sriyati et al. (2025) can be replicated across different teacher populations and

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institutional settings. Future research should employ stronger comparative designs where feasible and report standardized statistical indicators, such as mean differences, effect sizes, confidence intervals, and significance values, to facilitate comparison across studies. Longitudinal research would further help determine whether learning gains, scientific understanding, cultural awareness, and conservation-related outcomes are sustained after the immediate intervention period.

Future module development should also incorporate student and community perspectives from the earliest stages of research. Rather than treating students solely as recipients of completed modules and communities solely as sources of ethnobiological information, researchers could involve both groups in needs assessment, content selection, prototype development, and evaluation. This participatory approach may improve cultural relevance while also reducing the risk of representing local knowledge selectively or outside its original social context.

Finally, future systematic reviews could expand the search to additional international databases and multilingual sources, apply independent duplicate screening and data extraction, and use formal risk-of-bias assessment where appropriate. These improvements would strengthen the methodological robustness of the evidence base and provide a more reliable basis for determining when and under what conditions local community ethnobiological knowledge contributes most effectively to senior high school biology teaching.

CONCLUSIONS

This systematic review synthesized 22 sources published between 2021 and 2026 examining the integration of local community ethnobiological knowledge into senior high school biology teaching modules. The findings indicate that ethnobiological knowledge, particularly ethnobotanical knowledge related to medicinal and food plants, can be meaningfully mapped onto biology curriculum content, especially biodiversity, classification, and ecosystem topics. Across the reviewed studies, ethnobiology-based modules generally demonstrated high levels of expert validity, positive student responses, and measurable learning gains, although the magnitude and indicators of effectiveness varied across studies and should therefore not be interpreted as directly comparable. Preliminary comparative international evidence, together with findings from teacher-training research, suggests that ethnobiology-based instruction and teacher capacity development are promising and potentially transferable, but further evidence from diverse educational and cultural contexts is needed before broader generalizations can be made.

The review also identifies several persistent gaps in the current evidence base. Ethnobiology-based module development remains concentrated on biodiversity and closely related topics, while areas such as biotechnology and human physiology receive comparatively limited attention. Teacher preparation and access to structured training remain important implementation challenges, although the available teacher-training evidence suggests that these competencies can potentially be strengthened through targeted professional development. Student and community participation in the formative stages of module development also remains limited and insufficiently documented.

Future development should therefore adopt a topic-first approach, beginning with underrepresented biology topics such as biotechnology or human physiology and systematically

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identifying relevant local ethnobiological knowledge that can provide scientifically appropriate learning contexts. Expanded teacher training, meaningful involvement of students and local knowledge-holding communities, and stronger multi-region and longitudinal evaluation are also needed. These strategies can strengthen the cultural relevance, scientific alignment, and educational effectiveness of teaching modules while providing a more robust evidence base for determining how and under what conditions local community ethnobiological knowledge can contribute to senior high school biology education.

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