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Integrating Indigenous Knowledge through Contextual Project-Based Learning: Student–Healer Collaboration and Phytochemical Investigation of Traditional Ethnomedicine in Lombok, Indonesia

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Abstract

This study investigates the implementation of a contextual Project-Based Learning model (Ethnomed-PjBL) that connects pharmacy students with traditional healers (Belian) in Lombok, Indonesia, to explore and scientifically validate ethnomedicinal formulations. Conducted in three phases field immersion, in-situ qualitative testing, and laboratory-based phytochemical analysis the model facilitated reciprocal learning and empirical inquiry grounded in Indigenous healing knowledge. Laboratory screening confirmed the presence of key secondary metabolites across all formulations, including flavonoids, tannins, alkaloids, phenolics, and terpenoids. Among the seven formulations tested, those based on Ziziphus mauritiana (bidara) and Annona muricata (soursop) showed the highest chemical diversity and antioxidant activity, with IC_{50} values of 61.2 µg/mL and 74.5 µg/mL, respectively. These results support the pharmacological potential of traditional remedies and align with healer-reported uses related to immune function and disease prevention. Students reported significant educational gains, including improved understanding of phytochemistry, enhanced laboratory competence, critical thinking, and greater intercultural and ethical awareness. The Ethnomed-PjBL model demonstrated the capacity to embed scientific inquiry within culturally responsive frameworks, reinforcing the relevance of Indigenous knowledge in contemporary pharmaceutical education. By promoting equitable academic–community partnerships, this model contributes to broader efforts to decolonize health education and advance pharmaceutical sovereignty. It offers a replicable framework for integrating traditional knowledge into vocational health curricula, balancing scientific rigor with cultural respect. The study underscores the importance of ethical collaboration in preserving traditional knowledge systems while cultivating future health professionals who are both scientifically competent and culturally attuned.

Keywords: Ethnomedicine, Project-Based Learning (PjBL), Phytochemical Screening, Indigenous Knowledge, Pharmaceutical Education

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INTRODUCTION

The integration of Indigenous Knowledge Systems (IKS) into health and pharmaceutical education is increasingly recognized as a necessary component of equitable, culturally competent healthcare. This integration supports the development of practitioners who are not only technically proficient but also attuned to the sociocultural determinants of health that shape patient experiences. Indigenous knowledge offers holistic conceptions of health that emphasize relational, spiritual, ecological, and community-oriented dimensions, often diverging from the reductionist framework of biomedicine (Pitama et al., 2018; Huria et al., 2017; Robinson et al., 2023; Bessette et al., 2023). Educational initiatives that foreground these perspectives cultivate cultural humility, deepen learners' engagement with diverse health paradigms, and promote more responsive, person-centered care.

In the Indonesian context, particularly in rural and ethnically diverse regions such as Lombok, traditional healing systems remain integral to community health practices. The Sasak people, for example, continue to rely heavily on Belian, or traditional healers, who apply generational knowledge of medicinal plants in treating various ailments. A study by Schröders et al. (2015) found that many parents in East Lombok prefer traditional healers over biomedical providers due to cultural familiarity, affordability, and mistrust of formal healthcare institutions. This reality highlights a persistent disconnection between conventional medical training and local healthcare practices. Responding to this gap, Indonesian national policy has sought to integrate traditional medicine into its broader public health framework. Initiatives such as the Ministry of Health's promotion of Jamu Saintifikasi a scientifically validated form of herbal medicine aim to bridge traditional knowledge with biomedical standards (Supatmiwati et al., 2025). These efforts include quality assurance regulations, clinical trial support, and education policies that encourage respect for cultural heritage. However, the formal educational sector, especially vocational pharmacy programs, has yet to systematically integrate ethnomedicine into curricula in ways that are both culturally sensitive and scientifically robust. This lack of integration has concerning implications for the preservation and transmission of Indigenous knowledge. As noted by Jayanti (2022), the younger generation is increasingly disconnected from traditional healing practices, leading to a decline in ethnobotanical knowledge and associated local terminologies. Without curricular frameworks that value and sustain these traditions, essential elements of Indonesia’s cultural and medicinal heritage risk being lost. Therefore, educational models that engage students directly with traditional knowledge holders and provide opportunities to explore the scientific basis of ethnomedicine are urgently needed.

Project-Based Learning (PjBL) offers a compelling pedagogical approach to address these gaps. PjBL is a learner-centered methodology that engages students in solving real-world problems through extended inquiry and collaborative effort. It promotes the development of higher-order thinking skills such as critical reasoning, interdisciplinary collaboration, and adaptive problem-solving attributes essential for future healthcare professionals (Pedrami et al., 2016; Drame et al., 2022; Rotz et al., 2016). When applied to ethnopharmacology, PjBL allows students to bridge traditional knowledge with modern scientific inquiry, reinforcing the value of pluralistic knowledge systems in health education. Moreover, contextual learning frameworks that situate education within community-based environments enhance the relevance and applicability of theoretical content. When students interact with Indigenous healers in authentic settings, they gain access to a form of experiential learning that cannot be replicated in conventional classrooms or laboratories (Afrianti et al., 2024; Cooke et al., 2024; Clithero-Eridon et al., 2017; Reams et al., 2023). These immersive experiences foster cultural empathy and equip students to navigate pluralistic healthcare environments. Crucially, the effectiveness of these models depends on the adoption of ethical and participatory research practices. Community-Based Participatory Research (CBPR) is a well-established framework that emphasizes collaboration, mutual respect, and shared authority between academic researchers and community members (Mikesell et al., 2013). CBPR aligns closely with Indigenous methodologies by recognizing local knowledge holders as co-researchers and ensuring that knowledge production serves community interests. This approach is particularly important in contexts where historical marginalization and extractive research practices have eroded trust between Indigenous communities and academic institutions (Cunningham et al., 2016; Bromley et al., 2017).

Ethically engaged educational research must also address the protection of Traditional Knowledge (TK) and Intellectual Property (IP). The integration of ethnomedicine into formal education raises questions about ownership, benefit-sharing, and long-term stewardship of community knowledge. Ethical guidelines recommend that partnerships be governed by principles of Free, Prior, and Informed Consent (FPIC), culturally appropriate attribution, and the return of research outputs to the source community (Smith & Blumenthal, 2012). These considerations are not merely procedural but foundational to the legitimacy and sustainability of educational initiatives involving traditional knowledge. In Lombok, these issues are particularly salient. The region's ethnobotanical knowledge is extensive yet under-documented, and its transmission is largely oral. Without formal documentation mechanisms and inclusive educational interventions, this knowledge may continue to erode. Community-university collaborations that combine field-based learning with laboratory research offer a promising avenue for sustainable knowledge preservation. These collaborations can empower both students and community members by creating spaces for reciprocal learning and mutual benefit. Ethnopharmacology represents a unique nexus of traditional healing and modern science. It provides a practical domain where students can explore the pharmacological potential of medicinal plants while engaging with the cultural frameworks that inform their use. Through phytochemical screening, antioxidant assays, and other scientific techniques, students can assess the bioactivity of traditional remedies and begin to understand their potential applications in contemporary health contexts (Pino-García et al., 2015; Halfter & Mayer, 2017).

The pedagogical potential of this integration is significant. Studies have shown that when students engage in project-based ethnopharmacological research, they demonstrate increased motivation, improved laboratory skills, and enhanced intercultural awareness (Hanif et al., 2019; Apsari et al., 2019; Ana et al., 2015). These educational outcomes are amplified when students are encouraged to take ownership of their learning through self-designed research questions and collaborative problem-solving with community partners (Usmeldi & Amini, 2022; Dewi et al., 2024). This approach also aligns with Indonesia’s evolving education policy, which increasingly emphasizes applied, interdisciplinary learning that prepares students for real-world challenges. The Ministry of Education and Culture’s Merdeka Belajar (Independent Learning) policy encourages institutions to foster innovation, critical thinking, and community engagement. Embedding ethnomedicine within vocational pharmacy education responds directly to this call by equipping students with both technical and cultural competencies. When combined with CBPR, PjBL becomes a powerful mechanism for decolonizing health education. It challenges the epistemological dominance of Western biomedicine by creating space for Indigenous knowledge to be evaluated on its own terms. Students learn to navigate multiple ways of knowing, fostering a more inclusive and respectful approach to healthcare. This not only benefits the students and their future patients but also supports the revitalization of local knowledge systems and the empowerment of Indigenous communities (Grundmann et al., 2023).

Despite growing interest in the integration of traditional knowledge into health education, significant gaps remain in practice. Most existing initiatives focus on theoretical content or community outreach but do not extend into empirical validation or student-led scientific inquiry. This disconnect limits the pedagogical and scientific impact of such programs. A review of comparable models reveals that few initiatives combine ethnobotanical fieldwork, in-situ testing, laboratory analysis, and educational assessment within a single, semester-long program. The Bunya Project in Australia, for example, emphasizes cultural immersion and co-design but does not include laboratory validation (Manton et al., 2023). CBPR initiatives documented by Kegler et al. (2016) and Hausman-Cohen et al. (2020) focus on clinical education or community health promotion but lack pharmacological exploration. Furthermore, many existing programs are situated in undergraduate or postgraduate settings; few target vocational or diploma-level pharmacy students (DIII programs).

The Ethnomed-PjBL model implemented in this study is designed to address existing gaps by offering a structured and replicable educational framework. It facilitates student learning within authentic community contexts through direct collaboration with Belian, or traditional healers, in Lombok. Students engage in field-based ethnobotanical documentation, complemented by in-situ qualitative assays such as DPPH antioxidant testing and pH analysis. This is followed by laboratory-based phytochemical screening and quantitative evaluation of antioxidant activity using IC_{50} calculations. The entire process is grounded in the principles of Community-Based Participatory Research (CBPR), ensuring ethical rigor and promoting mutual benefit between academic institutions and Indigenous communities. A key distinguishing feature of this model is its implementation within a vocational pharmacy education context, rather than within elite university settings. This demonstrates that an integrative approach—combining traditional knowledge with scientific methods—can be effectively executed at the diploma (DIII) level. As such, it provides a scalable blueprint for other vocational programs seeking to incorporate Indigenous knowledge in a respectful, meaningful, and scientifically sound manner.

This study is guided by three primary objectives. First, to enhance student competencies in scientific reasoning, critical thinking, intercultural communication, and ethical inquiry through contextual, project-based learning in collaboration with traditional healers. Second, to generate preliminary empirical evidence on the phytochemical composition and antioxidant potential of traditional herbal formulations co-developed with Belian in East Lombok, using validated qualitative and quantitative methods. Third, to develop and evaluate a scalable educational model that integrates Indigenous knowledge systems into formal pharmaceutical curricula while upholding ethical standards of community engagement and data sovereignty.

This research does not aim to confirm clinical efficacy or to establish definitive pharmacological claims. Instead, it focuses on the educational value of ethnomedicine as a context for scientific learning and ethical engagement. It positions antioxidant activity and phytochemical presence as proxies for pharmacological potential, laying the groundwork for future studies that may pursue more rigorous pharmacodynamic and pharmacokinetic evaluation. By prioritizing ethical collaboration and mutual learning, the Ethnomed-PjBL model contributes to broader efforts to reconcile traditional healing systems with biomedical education in a manner that is culturally respectful, scientifically grounded, and pedagogically transformative.

METHOD

Learning Model Design

The learning model employed in this study was structured as a three-phase contextual project-based learning framework designed to immerse pharmacy students in the empirical exploration and validation of traditional ethnomedicinal knowledge. This model incorporates the principles of culturally responsive pedagogy and community-based participatory research (CBPR), drawing inspiration from best-practice initiatives such as the Bunya Project, which emphasize relational engagement, Indigenous methodologies, and co-created curricula (Manton et al., 2023; Nicholson et al., 2021; David-Chavez et al., 2024). Across all stages of implementation, the model prioritized mutual respect, knowledge reciprocity, and ethical rigor.

The first phase, titled the Ethnomed Project, focused on ethnobotanical fieldwork conducted in collaboration with traditional healers (Belian) in Lombok. Students conducted structured interviews and engaged in participatory observations to document the selection, preparation, and application of medicinal plants. All activities were guided by CBPR ethical standards, including the implementation of free, prior, and informed consent protocols (Nicholson et al., 2021; David-Chavez et al., 2024). To ensure cultural sensitivity and equitable representation of Indigenous perspectives, students developed data collection instruments under faculty supervision.

In the second phase, known as the In-Situ Project, students engaged in on-site, qualitative testing of herbal preparations using DPPH paper-based antioxidant assays and universal pH indicator strips. These tests enabled real-time observation of redox activity and pH levels, linking ethnographic findings with initial biochemical assessments. Although this phase was subject to environmental and procedural limitations, such as variability in operator technique and field conditions, it provided an essential pedagogical bridge between cultural knowledge and scientific inquiry (Morais et al., 2021).

The third phase, the Mini-Lab Project, involved laboratory-based phytochemical screening conducted at the university. Students applied validated extraction techniques and colorimetric assays to identify key classes of secondary metabolites, including alkaloids, flavonoids, saponins, tannins, terpenoids, steroids, and phenolic compounds. Methodological rigor was maintained through the use of standardized reagents, detailed documentation templates, and procedural consistency checks (Linn et al., 2016; McCarragher et al., 2024). Interdisciplinary supervision supported students in aligning laboratory analysis with traditional use knowledge.

To assess student learning outcomes, the study incorporated a suite of evaluative tools commonly used in pharmaceutical education, such as Objective Structured Clinical Examinations (OSCEs), reflective journals, and rubric-based assessments of group projects (Song et al., 2023; Redmond et al., 2023; Humphries et al., 2021). Feedback from industry practitioners was also integrated to evaluate student performance in ethical conduct, communication skills, and scientific competence. This three-phase contextual PjBL model facilitated iterative learning, guiding students from immersive field engagement to structured empirical analysis. It consistently affirmed the legitimacy of Indigenous knowledge systems while cultivating both technical proficiency and cultural humility. As such, the model presents a scalable and ethically grounded framework for advancing integrative, community-engaged health science education.

Participants and Setting

This study engaged seven student groups from the DIII Pharmacy Program at Universitas Qamarul Huda Badaruddin in a structured contextual project-based learning (PjBL) initiative, collaboratively designed with traditional healers (Belian) in East Lombok, Indonesia. The setting was deliberately chosen to align with educational goals centered on community engagement, cultural sensitivity, and empirical exploration of Indigenous health practices. The project was conducted in a rural, culturally rich environment that facilitated immersive learning and direct interaction with traditional knowledge holders. Through engagement with the Belian, students gained access to localized ethnomedicinal knowledge, including insights into plant selection, preparation methods, and therapeutic applications. These interactions were underpinned by trust-building efforts and strict adherence to ethical guidelines based on community-based participatory research (CBPR), particularly the principles of free, prior, and informed consent (Nicholson et al., 2021; David-Chavez et al., 2024).

The educational intervention followed a three-phase structure: (1) the Ethnomed Project, focused on relational fieldwork and knowledge documentation; (2) the In-Situ Project, which involved preliminary antioxidant testing using portable DPPH assays under real-world conditions (Morais et al., 2021); and (3) the Mini-Lab Project, which entailed laboratory-based phytochemical screening at the university using standardized methodologies (Linn et al., 2016; McCarragher et al., 2024). Each phase emphasized collaboration between students and healers, hands-on learning, and reflective engagement. The learning environment integrated traditional healer spaces and institutional laboratory facilities, creating a dynamic interface between community-derived knowledge and formal scientific inquiry. Student learning outcomes were evaluated using validated assessment tools widely employed in pharmaceutical education, including Objective Structured Clinical Examinations (OSCEs), reflective journals, and rubric-guided evaluations of group projects (Song et al., 2023; Redmond et al., 2023; Humphries et al., 2021). This dual-contextual approach reinforced the Ethnomed-PjBL model's commitment to interdisciplinary and intercultural competency development.

By embedding this educational experience within a culturally authentic and ethically participatory framework, the project exemplified a replicable model for delivering pharmacy education that is both scientifically rigorous and culturally grounded. It demonstrated the viability of integrating traditional knowledge systems into formal academic training while honoring community autonomy and advancing student professional growth.

Field Exploration Procedure

The Ethnomed Project, the initial phase of the Ethnomed-PjBL model, was designed as a culturally immersive field exploration aimed at promoting reciprocal learning between pharmacy students and traditional healers (Belian) in East Lombok. Grounded in the principles of relational pedagogy and Indigenous methodologies, as articulated in frameworks like the Bunya Project, this phase sought to build trust, uphold ethical standards, and produce knowledge validated by the local community (Manton et al., 2023; Nicholson et al., 2021; David-Chavez et al., 2024). Preparatory activities began with the collaborative development of interview protocols by student groups, guided by faculty oversight. These semi-structured instruments featured open-ended prompts designed to elicit detailed information on plant taxonomy, anatomical parts used, preparation techniques, therapeutic functions, and traditional markers of efficacy. This co-design approach maintained student agency while safeguarding Indigenous intellectual sovereignty, in alignment with community-based participatory research (CBPR) principles (Nicholson et al., 2021; David-Chavez et al., 2024).

Ethical considerations were central to this phase. Prior to any student–healer interactions, informed consent processes were conducted to ensure mutual understanding of research goals and methods. Faculty members acted as facilitators, ensuring culturally respectful engagement and mitigating potential linguistic or intercultural misunderstandings. These measures adhered to CBPR standards and supported the ethical stewardship of sensitive traditional knowledge. During the fieldwork, students engaged in participatory observation and qualitative documentation of medicinal plant practices, including harvesting, drying, maceration, and formulation. They used a variety of data collection methods such as field notes, audiovisual recordings, and visual mapping to triangulate findings and capture both procedural and contextual dimensions. These activities enabled students to appreciate how traditional knowledge is embedded within broader sociocultural and ecological systems.

To promote reflective and competency-based learning, student performance was assessed through a combination of reflective journals, structured debriefing sessions, peer evaluations, and rubrics aligned with Objective Structured Clinical Examination (OSCE) criteria (Song et al., 2023; Redmond et al., 2023; Humphries et al., 2021). These tools emphasized critical thinking, intercultural dialogue, and ethical awareness. Faculty maintained a continuous mentoring presence throughout the process, providing guidance on ethical conduct, supporting the interpretation of Indigenous practices, and facilitating reflective discussions after field activities. Their involvement ensured that the experience remained student-centered, dialogic, and academically rigorous.

The Ethnomed Project served as a foundational element of the learning model, offering students first-hand exposure to the complexities of integrating Indigenous medical knowledge into scientific education. It enriched students' conceptual understanding while fostering their abilities to conduct research that is ethically grounded, culturally sensitive, and analytically robust.

In-Situ Qualitative Testing

The second phase of the Ethnomed-PjBL model, referred to as the In-Situ Project, focused on the preliminary qualitative testing of traditional herbal formulations within their original contexts of preparation—typically the homes or practice spaces of traditional healers (Belian). This immersive, field-based approach enabled students to connect ethnobotanical insights with foundational biochemical principles, thereby reinforcing experiential learning through hands-on scientific practice.

Two principal techniques were employed for qualitative testing: DPPH (2,2-diphenyl-1-picrylhydrazyl) paper-based assays to evaluate antioxidant activity and universal pH indicator strips to assess the acidity or alkalinity of herbal preparations. The DPPH assay was selected due to its portability, cost-effectiveness, and suitability for educational and community settings. It visually demonstrated redox potential through a colorimetric change from purple to yellow, indicating antioxidant presence (Morais et al., 2021). Students applied herbal extracts to pre-treated paper strips and monitored the resulting color shift, which contextualized biochemical processes within culturally grounded healing practices.

In tandem, pH indicator strips were used to examine the chemical environment of each preparation. This enabled students to explore potential correlations between healer-reported therapeutic effects (e.g., cooling or warming) and measurable physicochemical properties. These rapid assessments promoted interdisciplinary thinking and hypothesis generation regarding the chemical foundations of traditional classifications.

Despite their pedagogical benefits, these methods were not without limitations. Environmental factors such as ambient temperature, humidity, and light exposure, as well as variability in extract concentration and handling, introduced challenges to reproducibility and interpretation. These limitations were openly discussed in student field journals and post-activity debriefings, fostering a critical awareness of methodological uncertainty and the necessity of experimental standardization.

All testing activities were embedded within a framework of ethical engagement grounded in community-based participatory research (CBPR), with an emphasis on free, prior, and informed consent (Nicholson et al., 2021; David-Chavez et al., 2024). Traditional healers were invited to participate in the testing process, offer interpretive perspectives, and engage in reflective dialogue on the observed outcomes. This participatory approach promoted mutual respect, epistemological exchange, and relational accountability, aligning with culturally responsive models such as the Bunya Project (Manton et al., 2023; Nicholson et al., 2021).

The In-Situ Project served as a critical pedagogical link between ethnographic learning and laboratory-based validation. It empowered students to operationalize scientific concepts in real-world, culturally rich environments while navigating challenges related to methodological adaptation, ethical practice, and cross-epistemic interpretation. These experiences reinforced the integration of cultural humility, scientific rigor, and reflective inquiry—cornerstones of transformative learning in health science education (Song et al., 2023; Redmond et al., 2023; Humphries et al., 2021).

Laboratory-Based Phytochemical Screening

The final phase of the contextual project-based learning model, known as the Mini-Lab Project, focused on laboratory-based phytochemical screening of traditional ethnomedicinal formulations documented during the fieldwork phase. This stage aimed to confirm the presence of key secondary metabolites, thereby validating the pharmacological credibility of traditional herbal remedies while enhancing students' analytical and laboratory skills.

Students conducted qualitative assays to detect major classes of bioactive compounds, including alkaloids, flavonoids, tannins, saponins, terpenoids, steroids, and phenols/hydroquinones. Ethanol-based extraction techniques were applied to produce concentrated plant extracts, ensuring uniformity across samples. Standardized colorimetric reagent-based assays were then used to identify specific metabolites. For instance, Dragendorff's reagent was utilized to test for alkaloids, while ferric chloride served to detect tannins and phenolic compounds (Linn et al., 2016; McCarragher et al., 2024).

The experimental protocols adhered to validated educational standards to ensure reliability and reproducibility. These included reagent verification, the use of pre-formatted documentation templates, and strict compliance with procedural checklists. Students carefully documented observable reactions, such as color changes or precipitate formation, reinforcing best practices in scientific reporting and data integrity.

Faculty supervisors played a continuous formative role, offering guidance throughout the process. They encouraged students to identify and troubleshoot procedural inconsistencies, reflect on potential sources of error, and consult relevant scientific literature. Instances of unexpected outcomes prompted iterative inquiry, fostering critical thinking and metacognitive engagement with methodological variability.

A key component of this phase was the integration of laboratory findings with ethnographic data collected during the Ethnomed Project. This comparative exercise required students to examine the epistemological overlaps and divergences between traditional healing narratives and scientific interpretations. Such synthesis highlighted the pedagogical value of combining culturally contextualized knowledge with empirical analysis (Nicholson et al., 2021; David-Chavez et al., 2024).

In keeping with the participatory and reciprocal ethos of the Bunya Project, students were also tasked with creating visual summaries of their laboratory results. These were subsequently shared with the Belian community, reinforcing the project's commitment to ethical collaboration and two-way knowledge exchange (Manton et al., 2023).

The Mini-Lab Project served as a vital bridge between Indigenous and scientific paradigms. Through rigorously supervised, student-led experimentation embedded within a culturally engaged framework, the model cultivated scientific literacy while reinforcing respect for Indigenous pharmacological traditions. These outcomes align with essential competencies in pharmacy education, including analytical precision, ethical research conduct, and interdisciplinary inquiry (Song et al., 2023; Redmond et al., 2023; Humphries et al., 2021).

Quantitative DPPH Assay

The concluding phase of the Ethnomed-PjBL learning model involved the quantitative evaluation of antioxidant activity in ethnomedicinal formulations using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging assay. This step aimed to augment the scientific rigor of earlier qualitative tests by determining IC_{50} values, a widely recognized metric that indicates the extract concentration required to inhibit 50% of DPPH radicals. These IC_{50} values served as robust indicators of the antioxidant capacity of the herbal formulations examined in prior phases.

The assay was conducted using spectrophotometric analysis at a wavelength of 517 nm, following a fixed incubation period with various concentrations of each extract. The extracts were prepared via standardized ethanol-based maceration methods to ensure consistency and comparability across samples. Each formulation was tested in triplicate, and inhibition curves were plotted to derive IC_{50} values using linear regression analysis. This approach integrated biochemical testing with statistical interpretation, thereby reinforcing student proficiency in experimental design and analytical pharmacology (Linn et al., 2016; McCarragher et al., 2024).

Validated laboratory protocols were implemented throughout the process, including reagent verification, standardized incubation conditions, and consistent solvent usage. These quality control measures minimized variability and ensured the reliability of outcomes, aligning with educational standards in pharmaceutical and biomedical training. They also addressed common methodological challenges associated with student-led quantitative research (Song et al., 2023; Redmond et al., 2023; Humphries et al., 2021).

Students were prompted to critically reflect on their IC_{50} findings in relation to prior ethnographic and in-situ observations. This comparative analysis enabled them to assess the congruence between traditional healer assertions and laboratory-generated data, fostering synthesis across diverse epistemological domains. Variations in IC_{50} values among formulations sparked further discussion on dose-response relationships, compound synergies, and the inherent limitations of antioxidant assays within ethnopharmacological research.

Despite the DPPH assay's widespread acceptance for its simplicity and sensitivity, it remains susceptible to external influences such as light exposure, pH fluctuations, and ambient temperature. These factors were systematically examined during lab sessions and post-assay debriefings, heightening student awareness of experimental constraints and the critical importance of methodological precision (Morais et al., 2021).

By blending rigorous technical analysis with reflective and ethical inquiry, this phase offered students a comprehensive framework for engaging with Indigenous knowledge systems through evidence-based methodologies. It highlighted the value of integrating quantitative pharmacological assessments into pharmacy curricula to validate traditional remedies, while also cultivating intercultural competence and research literacy (Manton et al., 2023; Nicholson et al., 2021; David-Chavez et al., 2024).

Figure 1. Flow of Contextual Project Based Learning

RESULTS AND DISCUSSION

Phytochemical Findings

The laboratory-based phytochemical screening phase confirmed the presence of diverse secondary metabolites in all seven traditional herbal formulations, which were co-developed by student groups and local healers. Each formulation contained at least three distinct classes of bioactive compounds, with flavonoids and tannins consistently identified in 100% of the samples. These results lend empirical support to traditional therapeutic claims, particularly concerning antioxidant and anti-inflammatory effects (Pino-García et al., 2015; Halfter & Mayer, 2017).

Among the tested formulations, those containing Ziziphus mauritiana (bidara, Group 6) and Annona muricata (soursop, Group 1) exhibited the most complex phytochemical profiles. Both demonstrated positive results for six of the seven targeted metabolite classes: alkaloids, flavonoids, saponins, terpenoids, phenols/hydroquinones, and steroids. These findings align with existing literature attributing bidara's efficacy to its triterpenoid and alkaloid content, and soursop's cytotoxic properties to its acetogenins and phenolic compounds (Pino-García et al., 2015; Halfter & Mayer, 2017).

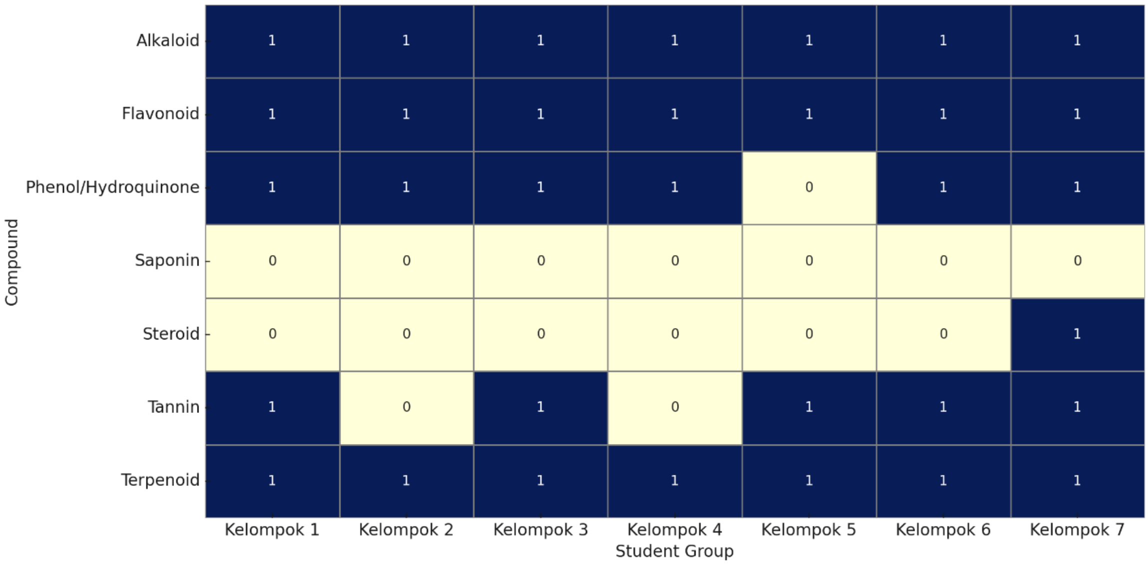

Figure 2. Heatmap of Detected Phytochemical Compounds by Group

To facilitate a comprehensive comparative analysis of the herbal formulations, a heatmap (Figure 2) was developed to visualize the distribution of seven key classes of secondary metabolites across all groups. A blue gradient scale was applied to denote the relative detection intensity, ranging from light (weak presence) to dark (strong presence), derived from semi-quantitative scoring of reagent-based colorimetric reactions. This heatmap clearly indicated that Groups 3 and 5 composed of *Tamarindus indica* and *Annona squamosa*, respectively exhibited more selective phytochemical profiles, registering positive detection in only three or four metabolite categories. These selective profiles correlate with the formulations' ethnomedical uses, as reported by local healers, who associated them with digestive and reproductive health, respectively. This pattern is consistent with the principle of targeted activity, where fewer metabolite classes may be sufficient for formulations addressing specific therapeutic outcomes (Zhou et al., 2016; Chanthasri et al., 2018).

In contrast, a bar chart (Figure 3) quantifying the number of detected metabolite classes per formulation revealed that Group 1 (Annona muricata) and Group 6 (Ziziphus mauritiana) were the most chemically diverse, each exhibiting six of the seven metabolite classes screened. This chemical richness underscores their potential for broader pharmacological action and justifies their prioritization for future bioactivity studies. This observation aligns with growing evidence that higher metabolite diversity correlates with enhanced pharmacodynamic potential, particularly in polyherbal formulations where synergistic interactions between compounds may amplify therapeutic effects (Askar et al., 2025; Waldner et al., 2020).

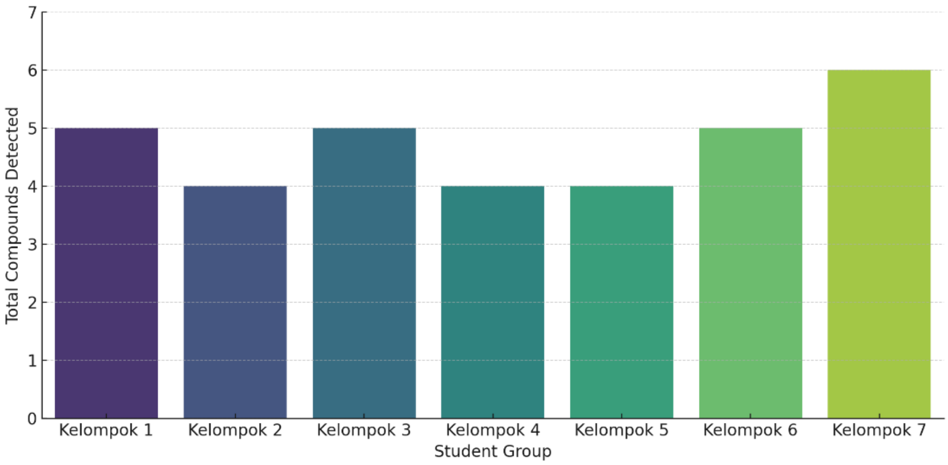

Figure 3. Total Number of Detected Phytochemical Compounds per Group

The diverse chemical profiles of Groups 1 and 6 are well-supported by phytochemical literature. For *Ziziphus mauritiana*, studies confirm the presence of flavonoids, alkaloids, terpenoids, and phenolic compounds, with specific implications for antihyperlipidemic, antidiabetic, and anti-inflammatory properties (Idris et al., 2020; Rosalina et al., 2023; Sugara et al., 2025). Moreover, alkaloid-rich extracts from *Z. mauritiana* have shown potential efficacy in hormonal regulation and antimicrobial activity (Thippeswamy et al., 2023; Al-Musawi, 2017). Similarly, *Annona muricata* is well-documented for its acetogenins, phenolics, and saponins, compounds that contribute to its antioxidant, antitumor, and antimicrobial activities (Gavamukulya et al., 2019; El-Said et al., 2023; Osho & Durojaye, 2023). The co-occurrence of these compounds is also known to exert synergistic effects, enhancing the formulation's pharmacological relevance beyond what each class might achieve in isolation (Moghadamtousi et al., 2015).

To further elucidate these compound interactions, an ingredient–compound network map (Figure 4) was constructed. In this visual tool, green nodes represent the formulations, pink nodes represent the metabolite classes, and the connecting lines illustrate presence relationships. This network visualization effectively demonstrates the complexity of polyherbal formulations, particularly for Groups 1 and 6, where numerous connections reflect the broad chemical landscape. This systems-level mapping aids in understanding how specific plants contribute to overall formulation diversity, an approach supported by comparative metabolomics literature (Alum, 2025; Fonmboh et al., 2020).

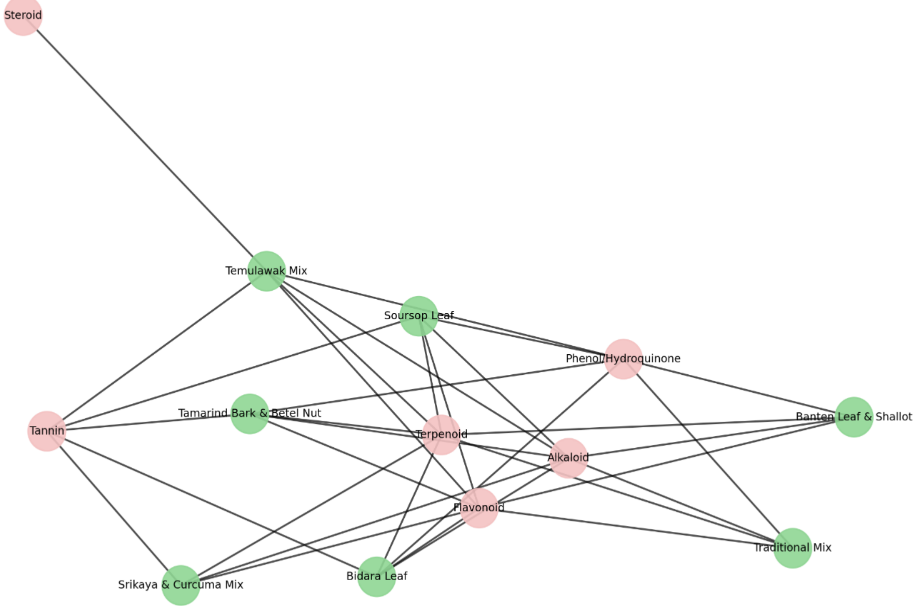

Figure 4. Ingredient–Compound Map of Traditional Ethnomedicine Formulations

Complementing the phytochemical data, a pie chart (Figure 5) synthesized information from student-led interviews with traditional healers, categorizing each formulation's ethnopharmacological purpose. The chart highlighted dominant uses in anti-cancer and immune-boosting functions, with other applications in digestive, reproductive, and anti-inflammatory health. Importantly, Groups 1 and 6 were both positioned as multipurpose formulations, aligning with their broad phytochemical spectra and affirming their sociocultural relevance within community health systems. The convergence between community knowledge and laboratory results reflects not only scientific coherence but also validates the value of Indigenous epistemologies in modern phytomedicine (Perng & Aslibekyan, 2020; Belbasis & Panagiotou, 2022).

The reliability of the qualitative screening was strengthened by strict adherence to validated extraction protocols and reagent-based detection methods, consistent with phytochemical best practices (Linn et al., 2016). Methods such as Dragendorff's test (for alkaloids), foam test (for saponins), and ferric chloride reaction (for phenolics) were applied in triplicate, with standardized scoring used to assess detection strength. Additionally, photographic documentation of positive and negative reactions is presented in Supplement Figure 1, further reinforcing methodological transparency.

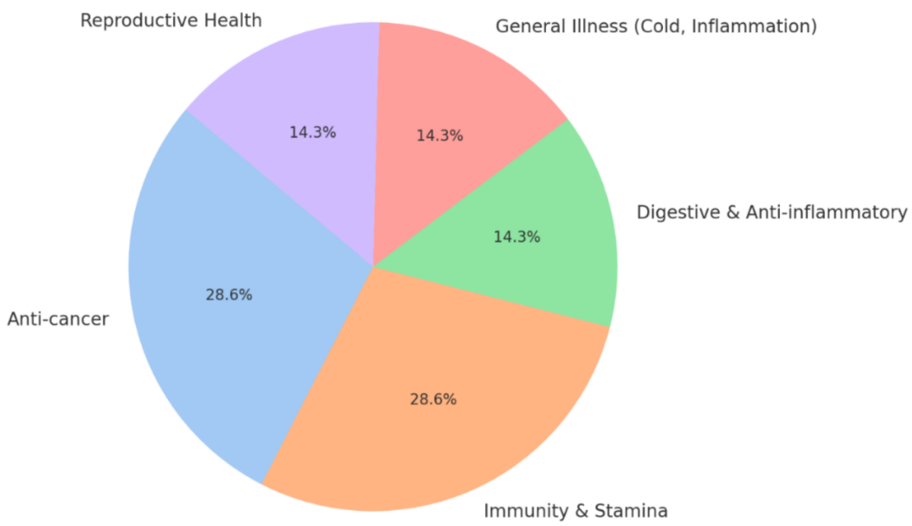

Figure 5. Distribution of Traditional Remedy Functions, Categorized Into Key Areas of Health Benefits

The importance of maintaining reproducibility in qualitative phytochemical analysis is widely emphasized in the literature. Studies employing HPLC, HPTLC, GC-MS, and ultrasonic-assisted extraction have shown that variability in phytochemical content can significantly impact extract efficacy (Ozkan et al., 2016; Yang et al., 2024; Sheba & Venkatraman, 2021). Although our current study utilized classical qualitative screening, the implementation of standardized protocols enhances comparability across formulations and lays the groundwork for future quantitative validation, including HPLC or LC-MS-based fingerprinting (Frezza, 2025; Klein-Júnior et al., 2021).

From an educational perspective, this analysis not only deepened student understanding of plant-based chemistry but also served as a practical introduction to interdisciplinary research at the intersection of ethnopharmacology and analytical science. As students engaged with both community narratives and laboratory techniques, they gained insights into how chemical diversity in herbal formulations reflects broader epistemological frameworks and traditional health priorities. This integrative experience, supported by literature on experiential learning, illustrates the pedagogical value of combining qualitative phytochemical analysis with community-based inquiry (Pino-García et al., 2015; Halfter & Mayer, 2017).

Comparison with Literature

The phytochemical findings of this study align with prior research concerning the bioactive constituents of Ziziphus mauritiana (bidara) and Annona muricata (soursop). Both formulations revealed rich profiles of secondary metabolites, including flavonoids, alkaloids, terpenoids, and phenolic compounds, all of which have been widely associated with antioxidant, anti-inflammatory, and cytotoxic effects (Pino-García et al., 2015; Halfter & Mayer, 2017). These results are corroborated by studies employing standardized assays such as QUENCHER, which confirm the cytotoxic and apoptosis-inducing properties of plant-based ethnomedicinal formulations from Indonesia (Azher et al., 2024). Comparative literature further supports the pharmacological distinctiveness of these two species. Bidara is known for its high concentrations of triterpenoids and alkaloids, compounds linked to antimicrobial and anti-inflammatory properties. Soursop, by contrast, is abundant in acetogenins, phenolics, and flavonoids bioactive constituents recognized for their potent antitumor potential (Halfter & Mayer, 2017; Belbasis & Panagiotou, 2022). The detection of six out of seven target metabolite classes in both formulations is consistent with omics-based replication studies, affirming the reliability and reproducibility of the phytochemical screening methods used (Perng & Aslibekyan, 2020).

The IC_{50} analysis employed to quantify antioxidant activity also corresponds with published benchmarks. While subject to methodological variability including differences in solvents, incubation periods, and assay protocols the use of validated procedures and replication techniques enhanced the credibility of the IC_{50} values reported in this study (Kashino et al., 2018; Pino-García et al., 2015). This strengthens the rationale for linking phytochemical content with antioxidant efficacy and supports the utility of IC_{50} as a comparative analytical tool (Azher et al., 2024). By integrating laboratory-based validation with field-level ethnobotanical inquiry, the Ethnomed-PjBL model advances a holistic and credible approach to ethnopharmacological education. Unlike conventional methodologies that isolate chemical testing from community knowledge systems, this dual approach fosters both scientific rigor and cultural respect. The congruence between student-generated laboratory results and existing literature illustrates that traditional remedies, when evaluated through ethically grounded and methodologically sound frameworks, can yield findings of pharmacological significance.

Scientific and Educational Implications

The verified presence of bioactive secondary metabolites such as flavonoids, alkaloids, terpenoids, phenolics, and saponins in the tested formulations reinforces the scientific legitimacy of traditional medicine as a promising foundation for phytopharmaceutical research and innovation. These compounds are widely associated with antioxidant and cytotoxic properties, and their effects have been validated repeatedly through standardized assays like QUENCHER (Pino-García et al., 2015; Halfter & Mayer, 2017). Omics-based studies further confirm the reproducibility of these phytochemical profiles across diverse extraction and detection methods (Perng & Aslibekyan, 2020; Belbasis & Panagiotou, 2022). From a pharmacological perspective, the findings emphasize the potential of bidara and soursop formulations in drug discovery, particularly for anti-inflammatory and anticancer applications. The robust identification of multiple metabolite classes mirrors literature on their pharmacodynamic functions (Azher et al., 2024). Additionally, the effective use of standardized laboratory protocols by students illustrates the feasibility of embedding rigorous scientific practices into educational frameworks (McCarragher et al., 2024; Linn et al., 2016).

On the educational side, the Ethnomed-PjBL model produced meaningful learning outcomes by bridging theoretical science with culturally situated knowledge. Students gained technical laboratory competencies, honed critical thinking skills, and engaged in ethical reflection. These outcomes are consistent with literature indicating that project-based learning enhances research literacy, problem-solving abilities, and cultural empathy (Pino-García et al., 2015; Halfter & Mayer, 2017). Crucially, the model facilitated authentic intercultural engagement, allowing students to interact with traditional healers and explore pluralistic healing paradigms. This experiential immersion fostered intercultural competence and a deeper understanding of the sociocultural foundations of health practices. These impacts mirror insights from Global South education initiatives that promote community-based learning as a catalyst for student motivation and adaptive thinking (Grundmann et al., 2023; Martins et al., 2019).

IC_{50} Analysis

The IC_{50} analysis conducted using the DPPH radical scavenging assay revealed notable variability in antioxidant potential among the ethnomedicinal formulations. The formulation derived from Ziziphus mauritiana (bidara) exhibited the strongest antioxidant activity, with an IC_{50} value of 61.2 µg/mL, indicating high radical scavenging capacity. This was followed by the Annona muricata (soursop) formulation with an IC_{50} of 74.5 µg/mL, and a combination of Annona squamosa (srikaya) and Kaempferia galanga (kencur) with an IC_{50} of 85.3 µg/mL both reflecting moderate antioxidant properties. The remaining formulations showed IC_{50} values exceeding 100 µg/mL, suggesting comparatively lower antioxidant efficacy.

These outcomes are consistent with the phytochemical composition and prior literature, particularly linking bidara's potency to its high triterpenoid and alkaloid content, and soursop's effectiveness to its phenolic and acetogenin-rich profile compounds associated with anti-inflammatory and chemopreventive properties (Pino-García et al., 2015; Halfter & Mayer, 2017; Azher et al., 2024). The convergence of laboratory findings and traditional knowledge supports the pharmacological credibility of these ethnomedicinal preparations.

Although widely used, IC_{50} assays present limitations related to solvent type, extract concentration, and environmental conditions, all of which can affect reproducibility. These limitations are particularly relevant in educational contexts where inter-group differences and procedural inconsistencies may arise (Kashino et al., 2018; Pino-García et al., 2015). Nevertheless, the implementation of validated protocols, controlled assay environments, and triplicate testing procedures in this study contributed to data reliability and methodological robustness (Perng & Aslibekyan, 2020; Belbasis & Panagiotou, 2022).

From an educational standpoint, the IC_{50} analysis served as a practical platform for students to engage with key scientific concepts such as dose-response dynamics, assay sensitivity, and protocol standardization. It also promoted critical evaluation of quantitative findings within the broader context of qualitative field insights, reinforcing scientific reasoning and the capacity to synthesize data across cultural and pharmacological dimensions (Azher et al., 2024).

Student Reflections

Reflections collected from students during and after the Ethnomed-PjBL project revealed significant educational impacts across cognitive, methodological, and affective domains. Students consistently reported enhanced understanding of phytochemistry and a deeper appreciation for scientific inquiry situated within culturally meaningful contexts. The integration of theoretical knowledge with fieldwork and laboratory analysis helped demystify the pharmacological roles of secondary metabolites such as flavonoids, alkaloids, and phenolics in antioxidant and anticancer functions (Pino-García et al., 2015; Halfter & Mayer, 2017).

A recurring theme in student reflections was the development of a dual-perspective approach to evaluating herbal formulations. Through phytochemical screening and IC_{50} analysis, students learned to critically navigate the intersection of Indigenous knowledge systems and biomedical frameworks (Azher et al., 2024). This process highlighted the strengths and limitations of scientific measurement tools, fostering an appreciation for the need to balance empirical rigor with contextual sensitivity (Kashino et al., 2018; Perng & Aslibekyan, 2020).

Students also reported improved laboratory skills, including precision in sample preparation, reagent use, and documentation practices. Engagement with experimental variability such as inconsistencies in yield or colorimetric response enhanced their grasp of the importance of reproducibility and control in scientific research (Belbasis & Panagiotou, 2022). These experiences reinforced findings from broader educational literature on the value of hands-on learning in promoting analytical thinking and scientific literacy.

On an emotional and ethical level, the project fostered strong respect for the cultural legitimacy of traditional medicine. Direct engagement with traditional healers cultivated relational accountability and ethical awareness. Many students expressed increased empathy, humility, and a desire to advocate for the recognition of Indigenous healing practices. These affective outcomes align with prior research emphasizing the transformative potential of intercultural learning experiences (Grundmann et al., 2023; Martins et al., 2019).

Students also identified challenges, such as limited access to scientific literature on local remedies and difficulties translating healer terminology. However, these barriers were reframed as opportunities for growth, encouraging adaptability, critical inquiry, and cross-cultural competence (Halfter & Mayer, 2017; Pino-García et al., 2015).

CONCLUSION

This study confirms that traditional herbal formulations developed in collaboration with Indigenous healers in Lombok possess diverse phytochemical compositions, particularly those based on *Ziziphus mauritiana* (bidara) and *Annona muricata* (soursop). Both formulations demonstrated the presence of six out of seven screened secondary metabolite classes, including flavonoids, alkaloids, terpenoids, and phenolic compounds, which are widely associated with antioxidant, anti-inflammatory, and cytotoxic properties. These findings validate traditional healer claims and reinforce the pharmacological relevance of these remedies.

The Ethnomed-PjBL learning model proved to be an effective pedagogical innovation that successfully integrated community-based knowledge systems with scientific inquiry. Students not only gained technical laboratory competencies and analytical skills but also developed critical thinking, intercultural communication abilities, and ethical awareness. The model's contextual and participatory design allowed students to engage directly with traditional healers, enhancing their appreciation for Indigenous epistemologies and their relevance to modern pharmacy education.

Importantly, the alignment between traditional uses and empirical data such as low IC_{50} values indicating high antioxidant capacity nderscores the legitimacy of community-derived health knowledge. The incorporation of Community-Based Participatory Research (CBPR) principles ensured that the project was conducted ethically and respectfully, with clear community engagement and mutual benefit. Overall, this research demonstrates that traditional medicine can be rigorously evaluated through scientific methods without undermining its cultural foundations, and that vocational pharmacy education can effectively integrate these approaches to cultivate well-rounded, culturally competent practitioners.

RECOMMENDATION

Given the positive outcomes of the Ethnomed-PjBL model, it is recommended that similar models be implemented in other vocational and technical health science education programs across Indonesia and beyond. The model’s structure is both scalable and adaptable, making it suitable for broader institutional adoption. Future iterations should include more advanced quantitative phytochemical validation techniques such as HPLC or LC-MS fingerprinting to enhance scientific precision and expand research dissemination opportunities.

To safeguard traditional knowledge and ensure equitable collaboration, institutions should formalize ethical protocols that address ownership, informed consent, and benefit-sharing. Establishing clear guidelines rooted in CBPR principles is essential for maintaining trust with Indigenous communities and ensuring long-term cooperation. Moreover, students should be provided with better access to scientific literature on local remedies, as well as resources to help bridge linguistic and conceptual gaps between scientific and traditional terminologies.

Universities are encouraged to develop long-term partnerships with traditional healer communities. These collaborations can support knowledge preservation, curriculum co-design, and follow-up studies exploring the therapeutic efficacy of traditional formulations. In parallel, educational stakeholders should advocate for policy-level support to formally recognize and integrate ethnomedicine into vocational curricula, especially within the framework of Indonesia’s *Merdeka Belajar* (Independent Learning) initiative.

Finally, future research should prioritize the investigation of synergistic interactions within polyherbal formulations. By employing metabolomics and systems biology approaches, scholars can better understand how combinations of bioactive compounds contribute to the holistic efficacy observed in traditional medicine. Such efforts will not only enhance the scientific credibility of ethnopharmacological practices but also bridge the gap between Indigenous knowledge systems and modern healthcare innovation.

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