

Integrating local wisdom into immune system worksheets: a systematic review of effects on science literacy and conceptual mastery

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ABSTRACT

Science literacy and mastery of the concept of the immune system are essential competencies in learning biology, but they are often constrained by the abstract and complex nature of the material. It is necessary to innovate teaching materials in the form of contextual Student Worksheets (LKPD) through the integration of local wisdom to bridge this gap. This study aims to analyze the results of previous research on the development of LKPD of the immune system based on local wisdom on science literacy and concept mastery. Using the Systematic Literature Review (SLR) method with article searches in the range of 2021–2026 and the PRISMA diagram guide, 12 final articles that met the inclusion criteria were selected. The results of the study show a tendency that the integration of local wisdom into LKPD has been proven to be able to improve science literacy, concept mastery, product validity, practicality, and learning effectiveness. However, empirical studies that specifically integrate local wisdom into immune system materials have not been found, so it has the potential to become a crucial research gap. In conclusion, the development of LKPD of the immune system based on local wisdom, especially through an ethnopharmacological approach, has great potential to become a contextual, meaningful, and relevant biology learning innovation to help students concretize abstract concepts of the body's defense mechanism in accordance with cultural reality.



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Introduction

Science literacy has been established as one of the essential competencies in 21st century education that must be mastered by students, especially in biology subjects, in order to equip them to face the dynamics of global problems (Sutrisna, 2021). The essence of science literacy does not only require students to memorize facts or concepts textually, but also requires a high level of cognitive ability to critically apply scientific knowledge in the decision-making and problem-solving process in real life (Yusmar & Fadilah, 2023). Although the urgency of this competency is very high, the achievement of science literacy of students in Indonesia is still at a worrying stage. Based on the report of the results of the study Programme for International Student Assessment (PISA) in 2022, the science literacy achievement of Indonesian students is still relatively low with an average score of 383, placing it below the international average (OCD, 2023; Pursitasari et al., 2022). This low achievement is closely correlated with students' difficulty in mastering biological concepts that are full of abstract, dynamic, and complex mechanisms (Yudistira et al., 2021). Therefore, a paradigm shift and

innovation in the science learning environment are needed to be able to bridge the difficulties of mastering biological concepts while training the ability to apply scientific optimally and contextually (Rahmadani et al., 2025).

One emerging innovation in science learning is the integration of local wisdom into open materials, including student worksheets. Local wisdom encompasses knowledge, values, practices, and traditions that have developed in society and been passed down through generations. Integrating these elements into learning can make the material more contextual and relevant to students' experiences. Thus, students not only learn scientific concepts abstractly but also understand their application in the social and cultural environments in which they live. Student worksheets that integrate local wisdom can also encourage more active and meaningful learning. Through exploration, observation, analysis, and reflection based on the local context, students have the opportunity to construct knowledge independently and develop higher-order thinking skills. Furthermore, this approach supports the preservation of local cultural values by connecting them to developments in modern science, so that education serves not only as a means of transferring knowledge but also as a medium for preserving cultural identity.

In bridging students' difficulties and creating a student-centered learning environment, the Student Worksheet plays a crucial role as an active teaching material that is able to stimulate learning independence (Nurahmawati et al., 2025). The ideal student worksheet should be designed to systematically guide students in discovering a scientific concept through investigation, observation, and problem-solving activities (Novitasari & Budijastuti, 2021). However, empirical realities in the field show that most of the LKPD instruments used by educators today are still very conventional, lack the context of the real environment, and have not been specifically designed to spark problem-solving skills or science literacy (Istiqomah, 2021). This condition indirectly causes students to be less trained in analyzing natural phenomena, so that biology learning activities become less meaningful because they only rely on theory (Lerian et al., 2022). On the other hand, the engineering and development of student worksheet, which is specifically oriented towards science literacy, has been proven to be academically able to boost students' mastery of concepts (Susilowati & Wisanti, 2023). The latest findings confirm that science literacy-based LKPD teaching materials are crucial because they are able to direct students to proactively explore contemporary scientific issues that challenge their scientific reasoning and argumentation (E. Kotimah et al., 2024).

One of the most innovative and representative approaches to transform student worksheet teaching materials into more meaningful is through the integration of local wisdom packaged in an ethnosience framework. Another increasingly relevant innovation is the digitalization of student worksheets (LKPD) into interactive e-LKPD. By utilizing digital technology, LKPD can be enriched with learning videos, simulations, animations, QR codes, and links to other learning resources. Students can access materials more flexibly and gain a more engaging learning experience. On the topic of the immune system, for example, e-LKPD can include animations about the body's immune response to infection or simulations of the interaction between antigens and antibodies, making complex concepts easier to understand. Ethnosience is a branch of science study that seeks to reconstruct and synthesize the traditional indigenous knowledge of a society (Indigenous Science) into the modern scientific concept system (Western Science), so that the subject matter becomes very intersecting with the social and cultural environment of students (Murwitaningsih & Maesaroh, 2023). The use of biology learning resources rooted in local wisdom has been proven to not only intrinsically increase students' motivation and deepen understanding of biological concepts, but also boost science literacy skills comprehensively. In the biological domain, the integration of local wisdom can be visualized in a variety of concrete examples, such as the study of taxonomy and the function of endemic medicinal plants Sambiloto to study the immune system and secondary metabolites (Purwadi et al., 2026), the use of fermentation methods in traditional foods Rusip or São Paulo for the topic of biotechnology, to the identification of organism interactions in the Sendang Made Ecosystem (H. Sari et al., 2025). More than just increasing the achievement of the academic dimension, the insertion of material from a cultural perspective also has a crucial impact in fostering students' love and awareness to maintain and preserve the nation's civilization heritage (Mellyzar et al., 2024).

Amidst the urgency of developing teaching materials that are more contextual, innovative, and relevant to students' lives, various approaches have emerged that attempt to connect scientific concepts with real-world experiences in their surroundings. One approach that is gaining increasing attention is ethnosience, which is the integration of scientific knowledge with local knowledge, culture, and traditional community practices. Through this approach, learning materials are no longer presented abstractly but are linked to phenomena close to students' lives, making them easier to understand and interpret. Thus, the discourse of ethnosience emerges as a response to the need to develop teaching materials that can increase student

engagement, strengthen scientific literacy, and preserve the values of local wisdom in the educational process.. Various previous independent research has massively explored project-based LKPD development practices (Septiani & Listiyani, 2024), science literacy study through local issues (Novanda et al., 2024), as well as the influence of understanding biological concepts separately. However, in the midst of the abundance of these studies, there has not been a systematic literature review that synthesizes and holistically integrates the three main variables, namely the development of LKPD, local wisdom/ethnoscience, and mastery of biological literacy in one integrated review framework (Wirama et al., 2023). This absence of comprehensive synthesis creates a research gap (Research gap) which is fundamental about how far the trend map, methodological effectiveness, and limitations of the application of ethnoscience teaching materials in the scope of formal science education in Indonesia are. Based on this gap footing, a methodology Systematic Literature Review (SLR) is absolutely necessary to map the latest publication trends, prove the effectiveness of local wisdom-based LKPD through solid evidence synthesis, and project empty gaps that must be answered in future research (Supriatna et al., 2025).

Based on previous research findings, there are still limitations in comprehensively explaining how the integration of local wisdom into learning worksheets affects students' scientific literacy and conceptual mastery. Therefore, this study aims to synthesize available empirical evidence through a systematic literature review to provide a more comprehensive understanding of the approach's effectiveness. (Kotimah et al., 2024). The essential contribution of writing this SLR article is projected to cover three stages: for the theoretical realm, this review will complement the epistemological foundations related to ethnopedagogy in the contemporary biology curriculum (Lestari et al., 2024); In practical terms, this article contributes to providing an empirical guide for practitioners and teachers in designing relevant draft LKPDs (Dewi et al., 2021); Meanwhile, in the policy realm, this paper serves as an evaluation basis for stakeholders in drafting science education regulations that respect local cultural assets (Ivaningtias et al., 2024). In conclusion, the presence of this systematic literature review article is an urgency and a fundamental step to realize contextual, meaningful, and responsive secondary level science education towards competent 21st century resources (Rahmadani et al., 2025).

Method

Types of Research and Research Questions

This study used a Systematic Literature Review (SLR) approach combined with bibliometric analysis to discover, initiate, and synthesize research findings regarding the integration of local wisdom in immune system learning worksheets and its impact on scientific literacy and conceptual mastery. The literature search process was conducted using Publish or Perish (PoP) version 8 with Google Scholar as the primary data source. The article selection stage followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Of the 512 identified documents, 78 duplicates were removed, leaving 434 documents for title and abstract screening. At this stage, 301 articles were excluded because they did not match the research topic. A total of 133 articles underwent full-text assessment, and 89 articles were eliminated because they did not meet the inclusion criteria, such as not discussing the integration of local wisdom, not using LKPD, or not reporting results related to scientific literacy or conceptual mastery. Thus, 44 articles met all requirements and were included in the qualitative synthesis and bibliometric analysis. (Kitchenham & Charters, 2007; Mengist et al., 2020). Meanwhile, bibliometric analysis is a quantitative and statistical evaluation technique used to map trends in scientific publications, analyze author collaboration networks, and identify relationships between keywords in a field of study (Hidaayatullaah et al., 2021; Verawati et al., 2023).

This study applies the combined systematic literature review (SLR) and bibliometric approach to identify, screen, and synthesize relevant publications, followed by quantitative mapping of research trends and thematic developments. (Liberati et al., 2009; Page et al., 2021). The main focus of this study is directed to answer three research questions (Research Questions / RQ) following: RQ1: What is the trend of publication of research on the development of LKPD based on local wisdom in 2021–2026?. RQ2: How effective is LKPD based on local wisdom on students' science literacy?. RQ3: How does LKPD based on local wisdom affect the mastery of biological concepts in immune system material?

Search Strategy and Selection Criteria

Literature data collection is carried out computationally using software Publish or Perish (PoP) latest version (version 8) by integrating the Google Scholar academic database (Dyah et al., 2025). Google Scholar was chosen because it has a wide range of access to publication of national and international journal articles and

Open Access. Literature searches were conducted using structured keyword specifications with the implementation of Boolean operators. The search strings entered are: "Development" AND ("LKPD" OR "student worksheet" OR "ethnoscience" OR "local wisdom" OR "local potential") AND "biology" AND "scientific literacy" AND "immune system". The publication time range is strictly limited to the period 2021 to 2026. Initial searches using these parameters yielded 114 articles. The next stage is to conduct screening using inclusion and exclusion criteria compiled based on the PICO approach framework (Population, Interest, Context) to ensure the relevance and validity of the literature (Herlinawati & Suhartini, 2025; Page et al., 2021; Xiao & Watson, 2019). The selection criteria are outlined in detail in Table 1.

Table 1. Article Inclusion and Exclusion Criteria

Criteria	Inclusions	Exclusion
Publication Type	Articles from scientific journals that are indexed by Sinta 1, Sinta 2, or reputable international journals (e.g. Scopus/DOAJ/Google Scholar are selected) and discuss the development of LKPD.	Proceedings, thesis, thesis, books, papers.
Types of Research	Scientific journal articles are indexed by Sinta 1, Sinta 2, or international journals published in reputable journals.	Descriptive research, pure experimentation, correlation, literature review, or article without product development.
Year of Publication	2021–2026.	Beyond the range of 2021–2026.
Language	Indonesian or English.	Languages other than Indonesian and English.
Topics (<i>Interest</i>)	LKPD that is integrated with local wisdom/ethnoscience for biology/science literacy.	It is not relevant to the LKPD or the local wisdom approach.
Material (<i>Context</i>)	The human immune system or biology in general.	Non-biological material.
Accessibility	Full text is available and accessible.	Full text is not available or the link is broken.

Data Extraction and Bibliometric Analysis with VOSViewer

The data obtained from the final selection results were extracted into two document formats for analysis purposes. First, metadata is extracted from the PoP device in the form of a RIS file (Research Information System) to maintain the integrity of the citation information (Fahrudin et al., 2023). Second, the data is also stored in CSV format (Comma Separated Values) to support the computation of annual publication trend analysis. The RIS file is then imported into the VOSviewer software version 1.6.19 to visually process bibliometric mapping (Wirama et al., 2023).

The bibliometric analysis carried out in VOSviewer includes three main evaluation parameters: co-occurrence analysis to map the correlation between keywords and identify the dominant themes of the study; Co-authorship analysis to detect collaboration networks between authors and institutional affiliates; and citation analysis to see the distribution of citations and the level of impact of a literature. The computation parameters in VOSviewer are set with a minimum limit of two (2) articles per author and a minimum number of citations per document of one (1) citation. The results are projected in the form of network map visualizations with automatic cluster coloring (the number of clusters is determined by the software logarithm), where the top items displayed are adjusted to the data saturation, generally in the range of the top 10 to 20 items.

Before being analyzed, article quality evaluation (quality assessment) was carried out for all 12 documents at the Included stage. The evaluation used a 1–4 scale assessment rubric for five indicators (Triandini et al., 2022): (a) clarity of research questions; (b) completeness of the methodology; (c) relevance to the topic of the review; (d) the quality of empirical data analysis; and (e) clarity of practical or theoretical implications. Articles with a total aggregate score of ≤ 10 were eliminated from the study, resulting in 12 final articles.

The process of synthesis of findings is carried out by a combined method. Publication trend analysis was executed quantitatively based on frequency calculations on CSV data to answer the annual output of the study (RQ1). The thematic analysis of the keyword cluster (network map) in VOSviewer serves as an issue mapping framework (RQ1). Furthermore, to answer the questions of the effectiveness of science literacy (RQ2) and mastery of the concept of the immune system (RQ3), a qualitative descriptive analysis was applied that constructed the empirical findings of the 12 selected articles into a comprehensive systematic narrative.

Article Selection Procedure Using PRISMA

The flow of article selection in this systematic review is guided by the protocol Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 version. The use of the PRISMA 2020 diagram ensures a transparent documented literature screening track record (Page et al., 2021; M. K. Sari et al., 2025). This process is executed as follows:

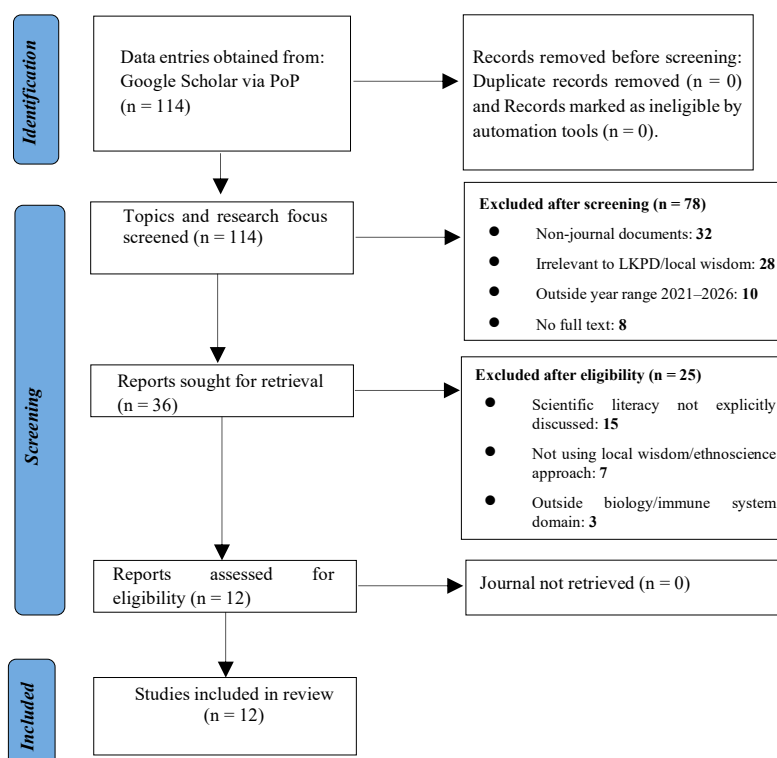


Figure 1. Article Selection Prism Diagram

Results and Discussions

Results

To enhance methodological transparency, article screening and eligibility assessment were conducted by two independent reviewers working separately according to pre-established inclusion and exclusion criteria. The level of agreement between reviewers was assessed using Cohen's kappa coefficient, with a κ value of 0.86, indicating excellent agreement. Discrepancies in the assessment results were resolved through discussion to establish context. Based on the selection process, which followed PRISMA guidelines, 114 articles were identified during the initial search phase. After removing duplicates and screening titles and abstracts, articles that did not meet the criteria were eliminated. Further eligibility assessment of full manuscripts yielded 12 articles that met all criteria and were included in the final synthesis. The synthesis of the 12 selected articles is presented in detail in Table 1.

Based on the data synthesis in Table 1, several crucial patterns of findings can be identified and provide a macro picture of the direction of research in this field. First, from the aspect of scientific substance, the most dominant biological material emerged was biodiversity and ecology, which were covered in 8 out of 12 articles (66.67%). This dominance indicates that local wisdom has a natural affinity with ecological concepts that are indeed directly intersecting with the living space of the community. Second, judging from the form of integration, ethnoscience/ethnobotany and local ecological potential are forms of local wisdom that are most often used as contexts, outperforming the form of material culture alone.

This shows a paradigm shift from simply introducing cultural artifacts, to the use of local empirical knowledge (indigenous knowledge) as a valid source of science learning. Third, there is a very strong methodological tendency, where all research uses the Research and Development (R&D) approach with ADDIE or 4D models, which are constantly collaborated with student-centered learning models such as Discovery Learning, Project-Based Learning (PjBL), and Problem-Based Learning (PBL). Fourth, the direction of product output shows that the majority of studies emphasize the combination of three aspects of

product quality as well as validity, practicality, and effectiveness with a focus on effectiveness often used as the main benchmark for success in improving science literacy and mastery of cognitive concepts.

Table 1. Synthesis of 12 Selected Articles on the Development of LKPD Based on Local Wisdom

Author & year	Product Type	Local Wisdom/Local Potential	Development Methods	Key Findings	Science/Mastery of Concepts
(Nisa et al., 2025)	E-LKPD (Liveworksheet)	Ethno-Vlog (Local ecological context)	R&D (ADDIE)	Valid, practical, and effective media	Significantly improve students' science literacy
(Abshor et al., 2025)	Interactive E-LKPD (Android)	Ethnoscience (Local wisdom of the community)	R&D	Valid and practical	Potentially improve critical thinking skills and science literacy
(Sajidi & Parmin, 2025)	E-LKPD	<i>Citizen Science Project</i> (Local environmental potential)	R&D	Effectively improve analytical thinking and collaboration skills	Supporting concept mastery through real-world environmental investigation
(Ardiansah & Zulfiani, 2023)	Interactive LKPD	Local environmental context	R&D (ADDIE)	Valid, practical, and effective practice of creative thinking skills	Improving mastery of the concept of environmental change
(Astuti & Kurniawati, 2025)	E-Worksheet	Integrated Ethnoscience	R&D	Valid, practical, and effective	Strengthen mastery of science process concepts and skills
(Suwandani et al., 2024)	E-LKPD	Lampung Filter Cloth (<i>Ethno-R&DSiMaYang</i>)	R&D	Effectively improve critical thinking skills	Mastery of science concepts through the integration of local cultures
(Hastiana et al., 2025)	LKPD	Swamp Ecosystem (Local potential of Kalimantan)	R&D	Valid, practical, and highly effective	Improving science process skills as the core of science literacy
(Annisaha et al., 2025)	Student Worksheet	Tidung Tribe Medicinal Plants (Nunukan)	R&D	Valid and practical	Supporting the mastery of the concepts of biodiversity and ethnobotany
(Tomi et al., 2024)	Student Worksheet	Local wisdom (Potential of local flora/fauna)	R&D (Detailed Learning + Discovery)	Valid, practical, and effective	Strengthening the mastery of the concept of biodiversity in a contextual manner
(Ansumarwaty et al., 2023)	Student Worksheet	Local Wisdom/PjBL	R&D (PjBL)	Effectively increase science literacy	Directly impact increasing science literacy
(Ayuwaningsih et al., 2025)	E-LKPD	<i>Socio-Scientific Issues</i> (SSI) local environment	R&D (PBL-SSI)	Effectively increase environmental literacy	Fostering science literacy through local socio-scientific issues
(Nurul Faizah Siregar & Sriyati, 2025)	Student Worksheet	Traditional Food of the Beauty of Tupperobu	R&D	Has the potential to increase biodiversity and tradition literacy	Strengthening the mastery of the concept of local biodiversity literacy

The temporal distribution of the 12 selected articles in the 2021–2026 range is presented in the following diagram.

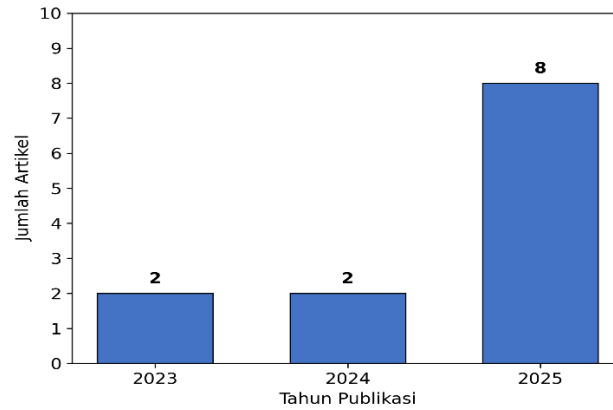


Figure 2. Article Distribution by Publication Year (2021–2026)

Data shows that no articles were found that met the inclusion criteria in 2021 and 2022, while in 2026 there was no publication due to data collection time limitations. The publication trend is accelerating in 2025 which accounts for 8 articles (66.67%). The surge in productivity from 2023 to 2025 is strongly correlated with the implementation of the Independent Curriculum which emphasizes contextual learning and projects to strengthen the profile of Pancasila students. This research was also triggered by the post-transition of digital learning, where researchers began to integrate the E-LKPD format with the context of local culture as an effort to save local wisdom in the midst of the flow of educational digitalization. To answer RQ2 and RQ3, mapping biological material is essential. The distribution of biological material in the 12 selected articles is presented in the following diagram.

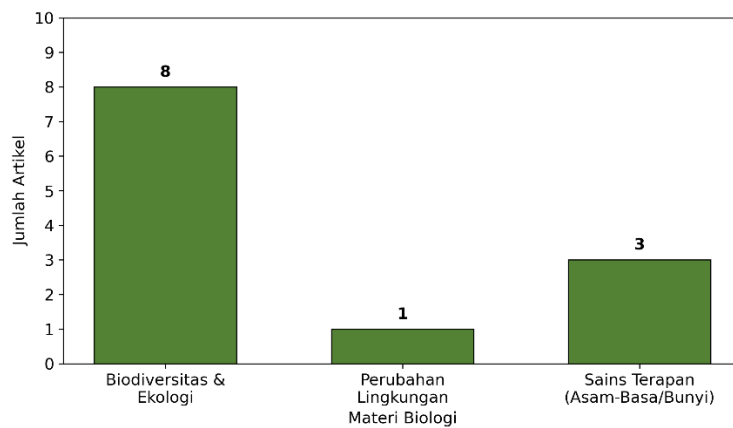


Figure 3. Distribution of Articles Based on Biology Material

The data findings empirically show that biodiversity and ecological matter dominate absolutely. It is important to note that in response to RQ3, there is not a single article out of the 12 selected articles that examines the development of LKPD based on local wisdom on immune system material. This indicates that the influence of LKPD based on local wisdom on the mastery of the concept of the immune system does not yet have an empirical basis in the selected literature, which subsequently becomes a research gap that is discussed in depth in the Discussion section.



Figure 4. Network Visualization

Bibliometric visualization reveals the structure of intellectual networks that are divided into two main clusters. The red cluster consists of the keywords scientific attitude, macroscopic fungi, module, pjbl, and science literacy. The green cluster is represented by local wisdom and designing student worksheets. Strong correlation lines connect local wisdom with concepts in red clusters. The size of the nodes of local wisdom, science literacy, and designing student worksheet was largest, indicating the highest occurrence density. This map represents a logical flow: the design of the LKPD intersects with local wisdom as input, to achieve science literacy and scientific attitudes as outputs through the PjBL approach. The presence of macroscopic nodes of fungi confirms the centrality of macroscopic topics (biodiversity), which contrasts with the absence of microscopic terminology such as the immune system.

Discussion

The combination of SLR methods and bibliometric analysis in this study has resulted in a comprehensive, objective, and replicable literature review, while presenting visual mapping that facilitates the identification of knowledge clusters (Liberati et al., 2009; Page et al., 2021). Through this approach, the following discussion will interpret the findings in depth to answer the main focus of the research, namely RQ2 (the effectiveness of LKPD on science literacy) and RQ3 (the effect of LKPD on the mastery of biological concepts, especially the immune system).

The findings of this SLR confirm that LKPD based on local wisdom has high effectiveness and a crucial position as a contextual teaching material that supports science literacy. Theoretically, science literacy requires students to be able to apply scientific knowledge in a real-life context. The local context used as the basis for LKPD is like the medicinal plants of the Tidung Tribe (Annisaha et al., 2025) and swamp ecosystems (Hastiana et al., 2025). It is empirically proven to help students understand scientific phenomena meaningfully because they are not just abstract constructs, but reality that they feel every day. Through the contextualization of ethnoscience, students are invited to connect theoretical concepts with empirical experience, which directly trains evidence-based argumentation skills (evidence-based argumentation). For example, LKPD-based Socio-Scientific Issues (SSI) local (Ayuwaningsih et al., 2025) forcing students to analyze environmental dilemmas from a scientific and cultural perspective, thereby raising awareness of conservation issues. Bibliometric maps further reinforce these findings; Close relationship between nodes Local Wisdom and Science Literacy affirms that local wisdom acts as a cognitive catalyst that activates the normative, critical, and procedural dimensions of science literacy.

In general, LKPD based on local wisdom has been proven to positively affect the mastery of biological concepts in macroscopic materials. The data show abstract concepts of biodiversity and ecology become much easier to understand when presented through ethnobotany (Nurul Faizah Siregar & Sriyati, 2025; Tomi et al., 2024). This is in line with the theory of meaningful learning (Meaningful learning) of Ausubel, where local wisdom acts as Advance Organizer which anchors new concepts into cognitive schemas that students are already familiar with. This LKPD consistently obtained high validity and practicality scores, and effectively improved cognitive learning outcomes (Ardiansah & Zulfiani, 2023; Astuti & Kurniawati, 2025).

However, specifically to answer RQ3 regarding immune system material, the results of this SLR state that currently there is no empirical evidence that tests the influence of LKPD based on local wisdom on the mastery of the concept of the immune system. The absence of a single article that raised immune system material from the 12 selected articles, as well as the absence of immunological terminology in the VOSviewer bibliometric cluster, is a very important null finding. Analytically, this emptiness is likely due to epistemological challenges; The immune system is microscopic, molecular, and abstract, making it much more difficult to contextualize directly into local wisdom that is generally macroscopic (such as flora, fauna, and ecosystems). However, it does not mean that local wisdom is not relevant to the immune system. The potential of ethnopharmacology such as the use of herbal medicine or local medicinal plants as immunomodulators (immunity enhancers) is actually a very rich local wisdom to contextualize the body's defense mechanisms. This literature gap actually opens up a very wide research gap.

Based on the critical synthesis above, several research gaps were identified that are urgent to be answered by future research. First, the substantive gap: there is still limited study of microscopic and physiological biological materials (such as the immune system, genetics, and coordination systems), even though the potential of local ethnopharmacology is very possible to be explored. Second, the methodological gap: there is still a lot of research that measures science literacy and concept mastery partially, so it is necessary to integrate the LKPD development design that is able to measure the two simultaneously. Third, the bibliometric gap: there is still a lack of large-scale data-based mapping studies that connect local wisdom variables with future biological topics (such as biotechnology and immunology).

This research has the theoretical implication that local wisdom and ethnoscience reinforce the foundations of contextual biology learning, where cultural knowledge serves as an effective cognitive scaffolding for the macroscopic domain. Practically, teachers and researchers can use these findings as a guide to designing valid, practical, and effective LKPDs. However, this review has limitations, namely the dominance of articles from certain geographical contexts (Kalimantan and Lampung) and the inability to provide empirical data related to immune system material due to the lack of literature. Therefore, follow-up research recommendations include: (1) the expansion of the exploration of local wisdom into the material of the immune system through ethnopharmacological approaches (traditional immunomodulatory contexts); (2) strengthening quasi-experimental design to measure the improvement of science literacy and mastery of immunology concepts in an integrated manner; and (3) the development of an interactive digital E-LKPD that is able to visualize microscopic immune mechanisms based on the macroscopic context of local wisdom, thereby bridging the gap between abstract concepts and the cultural reality of students.

Limitations

Although this systematic review adheres to the PRISMA principles and employs a structured literature search and selection procedure, there are several limitations that should be considered when interpreting the research results. First, the study selection process has the potential to introduce selection bias because it only includes articles that meet specific inclusion criteria and are available in the databases used. As a result, some relevant studies that are not indexed or do not meet the search requirements may not be identified. Second, this review does not specifically account for publication bias, or the "file drawer" issue, which is the tendency for studies with positive results to be published more frequently than studies with insignificant or negative results. This condition may lead to overly optimistic estimates of the benefits of integrating local wisdom into the LKPD (Regional Work Plan) compared to the actual situation. Third, the reviewed studies exhibit significant heterogeneity in various aspects, including study design, participant characteristics, educational level, implementation context, measurement instruments, and indicators of scientific literacy and conceptual mastery used. This variation limits the ability to make direct comparisons between studies and reduces the generalizability of the findings. Furthermore, this study presents a narrative synthesis of the available results and does not conduct a quantitative meta-analysis to calculate pooled effect sizes or heterogeneity statistics such as the I^2 or Q statistics. Therefore, statements regarding the effectiveness of local wisdom-based LKPD should be understood as tendencies supported by the majority of the studies reviewed, rather than as universally applicable quantitative estimates.

Conclusions

Based on the results of a Systematic Literature Review of 12 articles that met the inclusion criteria, this study indicates that most studies reported a positive relationship between the integration of local wisdom in Student Worksheets (LKPD) and improved scientific literacy, conceptual mastery, learning engagement, and the relevance of biology learning. Specifically, the integration of local cultural context in the immune system material is seen as helping students connect biological concepts to everyday experiences, potentially supporting a more meaningful learning process. However, these findings require caution. This study did not conduct a quantitative meta-analysis to calculate pooled effect sizes or heterogeneity statistics; therefore, the conclusions presented are based on a narrative synthesis of available research findings. Therefore, statements regarding the effectiveness of local wisdom integration are not intended to constitute universal causal evidence, but rather represent trends reported in the majority of the reviewed studies. The literature search was conducted through a systematic search of Google Scholar using Publish or Perish version 8, applying predetermined inclusion and exclusion criteria. Selected studies were then evaluated using appropriate quality assessment instruments, such as the Mixed Methods Appraisal Tool (MMAT) or the Joanna Briggs Institute (JBI) Critical Appraisal Checklist, depending on the study design. The synthesis was conducted narratively due to significant variation in study designs, sample characteristics, interventions, and reported outcome measures. This study also has several limitations. First, the literature search was limited to the databases used, so it is possible that not all relevant studies were identified. Second, the use of language publications may have excluded studies in other languages that could potentially yield different findings. Third, this study did not systematically include gray literature such as theses, dissertations, technical reports, or preprints, so the potential for publication bias remains a concern. Furthermore, heterogeneity in research methods, measurement instruments, and outcome indicators across studies limits the ability to make broad generalizations across learning contexts. Based on these limitations, further research is recommended to expand the scope of the baseline data, incorporate relevant gray literature, consistently assess research

quality, and conduct meta-analyses if sufficient data are available. This approach is expected to yield more robust quantitative estimates of the impact of integrating local wisdom into student worksheets on scientific literacy and conceptual mastery, particularly on the immune system.

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