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Integrating Local Wisdom and Education for Sustainable Development in Biology Learning: A Needs Assessment Study

Mahda Rizqina Maftuha [a, 1, *], Siti Sriyati [a, 2], Rini Solihat [a, 3], Izza Alfina Cahyani [b, 4]

[a] Magister Biology Education, Faculty Mathematics and natural science, Universitas Pendidikan Indonesia, Bandung-Indonesia
[b] Education Technology, Faculty of Education, Universitas Negeri Jakarta, Jakarta-Indonesia
[1] mahdarizqina@upi.edu; [2] sriyati@upi.edu; [3] rinisolihat@upi.edu; [4] izza.alfina.cahyani@unj.ac.id
* Corresponding author: mahdarizqina@upi.edu

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ABSTRACT

Local wisdom is the indigenous knowledge passed down through generations, encompassing values that can serve as an example for students to adopt a sustainable lifestyle. Integrating local wisdom into science education represents an innovation that can support Education for Sustainable Development (ESD), as local wisdom plays a crucial role in achieving environmental, cultural, and economic sustainability. This study aimed to analyze the need to integrate local wisdom and ESD content into biology learning materials in Pasuruan. The research employed a mixed-methods approach with an embedded design. Data were collected through questionnaires, interview guides, and document analysis sheets. The sample consisted of 2 biology teachers and 37 students selected through purposive, cluster random, and simple random sampling. The results revealed several critical gaps, including: 1) Alignment challenges with local wisdom in the Merdeka Curriculum and the Pancasila Student Profile; 2) The underutilized potential of biology-related local wisdom from the Tengger tribe in Bromo Tengger Semeru National Park; 3) The absence of locally contextualized biology learning resources that integrate ESD principles and local wisdom context. These findings contribute to biology education by providing empirical evidence of the urgent need for culturally responsive and sustainability-oriented learning materials in ecologically rich regions. Future research should focus on designing and empirically validating a local wisdom- and ESD-based learning resource to address the identified gaps and improve the quality of biology education in the Pasuruan area or in regions with similar characteristics.

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Keywords: Local wisdom, ESD, Needs Assessment

Introduction

Local wisdom is a body of knowledge developed from a community's diverse experiences and understanding of its environment (Schwann, 2018). The knowledge and values embedded in the worldview of indigenous peoples can foster behaviors that uphold mutual respect and environmental preservation (Sandoval, 2020). This aligns with research by Yuliana et al. (2017), which identified the local wisdom of the Ngata Toro community. The Ngata Toro community manages the forest by dividing it into six zones (*wanangkiki, wana, pangale, pahawa pongko, oma, and balingkea*) governed by rules for conservation and sustainable use. This zonation system reflects values of conservation, balance, sustainability, and cooperation, making it a relevant learning resource for students.

In the Merdeka curriculum, local wisdom is an aspect included in the Pancasila Student Profile's dimension of global diversity. This profile aims to help students preserve their noble culture and local identity while remaining open-minded when interacting with other cultures (Kemendikbudristek, 2022). Integrating local wisdom into learning is crucial in line with 21st-century demands, including science education with a multicultural approach, critical thinking skills, problem-solving, environmental literacy, and fostering students' love for their local culture (Gunstone, 2014; Kamilah & Suwarna, 2019). Furthermore, local wisdom is also relevant to achieving the SDGs and supports the implementation of ESD, which is the goal of SDG 4.

Schools, as educational institutions, play a strategic role in achieving the SDGs (Bariroh et al., 2024). According to Purwianingsih et al. (2022), many Indonesian biology teachers do not fully understand or integrate ESD into biology learning. The development of teaching materials and the scarcity of ESD-based learning resources remain significant challenges (Bramastia et al., 2025). ESD promotes participatory teaching methods that motivate and empower learners to alter their behaviors and take concrete actions toward sustainable development, while simultaneously developing competencies in critical thinking, future scenario-building, and decision-making (Perwitasari et al., 2023). ESD can be integrated into science education through various approaches, such as instructional materials, learning media, and instructional models (Purnamasari & Hanifah, 2021). In the context of achieving the SDGs, indigenous knowledge is crucial because diverse perspectives deepen understanding of global complexities and strengthen efforts toward sustainability (Sandoval, 2020). By applying local wisdom, sustainable development actions can be designed more holistically and with greater focus. This approach plays a crucial role, particularly in balancing rapid technological advancement, environmental carrying capacity, and socio-cultural values (Wahyuningtyas et al., 2025).

Biology education that incorporates local wisdom can stimulate students' active participation, strengthen their character, and improve their understanding by developing their interpretive abilities to decipher natural phenomena (Febrian et al., 2024; Putri & Usmeldi, 2020). Students will reflect on cultural traditions through a scientific approach to solve contextual problems relevant to life (Febrian et al., 2024). Integrating local wisdom and local potential into biology lessons can enhance students' ability to explore, understand, develop, and address existing local potential (Ule et al., 2021). Integrating local wisdom into learning is closely related to context-based learning. Connecting scientific concepts with daily cultural phenomena or activities can help students construct scientific concepts without abandoning their cultural identity, making the learning process more meaningful (Kasi et al., 2024). Existing societal cultures such as customs, traditional foods and beverages, etiquette, clothing, or arts can be used as examples for student learning, given that science is inseparable from daily practices in society (Hadisaputra et al., 2019). This aligns with Pertiwi & Rusyda Firdausi (2019), who state that teaching science in a more meaningful way involves giving students opportunities to directly observe scientific phenomena, natural changes, or real-world problems through the cultural activities surrounding them.

Based on initial observations at two schools in Pasuruan, teachers have not integrated local wisdom into their lessons, especially in biology. Pasuruan is an area with local potential, including the Bromo Tengger Semeru National Park (BTSNP). The park is home to the local wisdom of the Tengger tribe, which has been preserved to this day. Conservation areas can also serve as examples of local potential for learning because they are assets for preserving biodiversity, ecosystem balance, and environmental sustainability (Jacinda et al., 2024). Research by Maftuha et al. (2025) found that the ethnoscience of the Tengger tribe, the local potential of the BTSNP, and the collaboration between the Tengger community and stakeholders have great potential to be used as a learning resource for students in biology, specifically for the topic of ecosystems, as an effort to support ESD.

One way to integrate local wisdom into learning is by developing learning tools. Teaching materials are one such tool that can integrate local wisdom into the learning process (Mukhyati & Sriyati, 2015). Along with technological developments, the forms and types of teaching materials are changing. Digital teaching materials are now increasingly popular because they are more accessible, engaging, and can increase students' curiosity. One type of teaching material that can be used in learning is a module. A module is a systematically arranged teaching material that uses language appropriate for the student's age level and can be used for independent learning (Puspitasari, 2019). Along with technological developments, modules are now available not only in printed form but also in digital form (e-modules), which can be accessed on computers or smartphones (Febriani & Kustiyono, 2022). This aligns with Moreira et al. (2023), who stated that digital technology drives a profound transformation of instructional materials, including the conversion of traditional printed materials into digital educational resources. Developing biology e-modules that integrate the local potential and wisdom of an area will stimulate students' creativity and encourage them to apply cultural values in their daily lives (Aji & Pujiastuti, 2022; Sanjayanti et al., 2022).

Local wisdom has been theoretically acknowledged as a meaningful context for science learning. Its practical implementation in classroom settings, particularly in biology education, remains limited. Teachers in Pasuruan lack structured learning materials that authentically embed local wisdom from the Tengger community within an ESD framework. Without such resources, students are unlikely to develop sustainability values aligned with the Merdeka Curriculum. This gap highlights the need for contextually relevant learning resources that connect students' cultural environment with scientific concepts. Therefore, this study aims to analyze the need to integrate local wisdom and ESD content into biology learning materials in the Pasuruan area. The study addresses the following research question: How is the need to integrate local wisdom and ESD into biology learning evaluated based on curriculum analysis, learning analysis, and teaching material analysis?

Methods

This study used a mixed-methods design with an embedded approach, in which qualitative data (interviews and document analysis) were embedded within a predominantly quantitative design to provide contextual support and deeper interpretation of the questionnaire findings (Creswell, 2014). The instruments utilized were a questionnaire, interview guide, and document analysis sheet. The population of this study consisted of all tenth- and eleventh-grade students together with the biology teachers at four public senior high schools in Pasuruan. Biology textbooks used by the biology teachers were included as documentary data sources. The sampling procedures were determined according to the characteristics and objectives of each respondent group and data source as summarized in Table 1.

For the biology teachers and textbooks, purposive sampling was used. Two biology teachers from School A and one from another school, referred to as School B, were purposively selected based on their experience teaching ecosystem topics and were interviewed accordingly. In addition, the biology textbooks used by these teachers were also purposively selected as documentary data sources for analysis.

For the eleventh-grade students, cluster random sampling was employed, with the four public schools in Pasuruan served as the sampling clusters. In the first stage, one school was randomly selected from the four schools. In the second stage, one class from the selected school was randomly selected. All 31 students in the selected class were subsequently included as the student sample and completed the questionnaire. Eleventh-grade students were selected because they had already studied ecosystem and biodiversity topics relevant to local wisdom and local potential, allowing an examination of their learning experiences and evaluations following instruction on those subjects.

For the tenth-grade students, simple random sampling was employed to select six students from Schools A and B, each of whom was interviewed. Each eligible tenth-grade student had an equal probability of being selected as a participant. Tenth-grade students were selected because they had not yet covered ecosystem and biodiversity material, enabling an assessment of their general perceptions and learning needs regarding biology. Table 1 presents the number of respondents, sampling techniques, and school of origin for each group.

Table 1. Respondent identification, sample quantity, data collection, and sampling techniques

No	Respondent /Data sources	Qty	Data collection	School of Origin	Sampling techniques
1.	Biology teachers	2	Interviews	School A and B	Purposive sampling
2.	Students eleventh-grade	31	Questionnaires	School A	*Cluster random sampling*
3.	Students tenth-grade	6	Interviews	School A and B	*Simple Random sampling*
4.	Textbooks used by teachers	2	Document analysis	School A and B	Purposive sampling

In this study, the aspects used to analyze the needs consist of curriculum analysis, learning analysis, and teaching material analysis. The explanation for each aspect is presented as follows:

Curriculum analysis was performed by identifying the curriculum used in the two sample schools. This analysis aimed to determine the relevance of core competencies, teaching materials, and learning outcomes. The curriculum is the main foundation in education that directs the educational system and defines the profile of the student output to be shaped within society. The prevailing curriculum provides a direction that influences the entire teaching and learning process (Yaşar & Aslan, 2021). Learning analysis was conducted to understand the learning strategies currently used by teachers, their experience implementing local wisdom in teaching, and their experience integrating ESD into biology lessons. Teaching material analysis was conducted to understand the current use of biology teaching materials, the challenges or obstacles related to their use in biology lessons, and students' perceptions of what constitutes engaging and easy-to-understand teaching materials.

The qualitative data analysis, based on interviews with teachers and tenth-grade students, involved transcribing the interview results, followed by coding, thematic categorization, and fact condensation. The findings were subsequently interpreted descriptively. Codes were utilized to construct thematic descriptions that captured the complexity of the phenomena under investigation (Creswell & Guetterman, 2019). Interpretation was conducted by drawing comparisons between the findings and existing literature, as well as by providing recommendations regarding the study's limitations and directions for future research (Creswell & Guetterman, 2019).

Data analysis employed for questionnaire-based data collection involved calculating the percentage for each aspect using the following formula.

Percentage of each response category: $\frac{number\ of\ students\ who\ responded\ \text{"yes/ever" or "no/never"}}{total\ number\ of\ students}$x100%.

Data analysis for the descriptive qualitative book analysis was conducted by identifying the aspects to be examined in accordance with Table 4, then determining whether each book contained those aspects.

Results and Discussion

Perceptions of Teachers and Students Regarding the Need for Integrating Local Wisdom and ESD Content explained as follows:

1. **Curriculum Analysis**

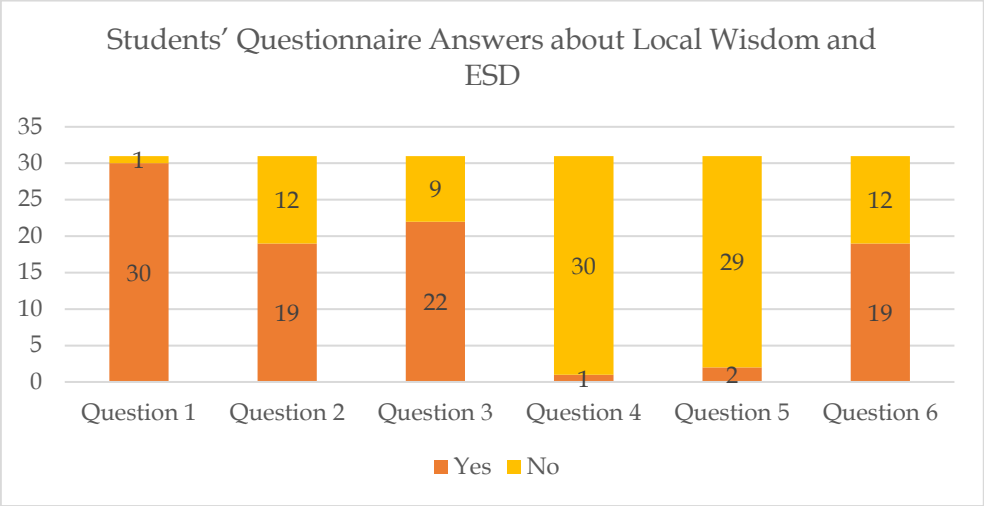
   Based on interviews with teachers about the curriculum used in their lessons, the Merdeka curriculum was used, with learning outcomes referring to the latest version. Phase E is used for tenth grade, and Phase F is used for eleventh and twelfth grades. In Phase E, the integration of SDGs is explicitly stated: "By the end of Phase E, students can be responsive to global issues and play an active role in providing solutions to problems. All these efforts are directed toward achieving the Sustainable Development Goals." However, in Phase F, there are no requirements that explicitly point to the SDGs.

   Education plays a crucial role in shaping the quality of human resources and producing a generation capable of competing globally. Several factors influence the learning process, including the presence of teachers, the curriculum used, and the availability of facilities or infrastructure. The success of the learning process is also determined by the teaching materials teachers use in the classroom (Muafiah et al., 2024). Biology education should not only focus on theoretical aspects but also encourage students to learn from their surroundings. The goal of biology education is to give students opportunities to engage directly in scientific activities and to build and develop their abilities (Sari et al., 2020; Usman et al., 2024).

2. **Learning Analysis**

   Based on interviews with teachers, it was found that the teacher from School A teaches biology using textbooks and student worksheets for some topics. The teacher from School B uses textbooks and practical work for some topics and occasionally uses student worksheets. Neither teacher has yet implemented local wisdom into their biology lessons, though they have done so during P5 projects. Neither teacher has a comprehensive understanding of the Tengger tribe's local wisdom. However, biology topics that have potential to be integrated with local wisdom include biodiversity, ecosystems, and environmental change. Regarding their knowledge of ESD, both teachers are unfamiliar with ESD and the SDGs, and therefore do not understand the urgency of integrating ESD into biology education.

   Based on interviews with tenth-grade students from two different schools, the analysis found that most students do not yet understand the definitions of local wisdom and local potential. This is because teachers have never provided information or instruction on these topics. Teachers currently use discussion, practical work, and independent assignments using textbooks. Students feel that these methods are somewhat helpful. However, one student suggested that teachers should explain topics more frequently or provide reinforcement after students complete assignments so that they can understand the material better. Students generally prefer active learning methods such as discussions, practical work, or observation activities because these methods significantly increase their motivation and understanding. Additionally, direct explanations from the teacher are also considered effective. Students are also motivated and can grasp concepts well when the material is presented with visual aids such as images, videos, and technology-based tools like PowerPoint presentations. Based on the analysis of the eleventh-grade student questionnaire on learning, the results are presented in **Figure 1.**



Note:
Question 1: Students' knowledge of local wisdom and local potential
Question 2: Students experience visiting BTSNP
Question 3: Knowledge of Tengger tribe's local wisdom
Question 4: Teacher experience in providing information about local wisdom
Question 5: Students' knowledge of the SDGs and ESD
Question 6: Teachers' experience teaching biology concepts in relation to environmental, social, and economic contexts

Figure 1. Students' questionnaire answers about local wisdom and ESD

Based on Figure 1, most eleventh-grade students are already familiar with the definition of local wisdom or local potential. This finding is not consistent with findings for Grade X students, who had not yet understood the concepts of local wisdom and local potential. It may be influenced by grade level, differences in school contexts, previous learning experiences, teacher practices, and students' exposure to local cultural and environmental concepts. Regarding their knowledge of the Tengger tribe's local wisdom, most students are familiar with some aspects, predominantly traditional art forms like dances and musical instruments, and *the Yadnya Kasada* ritual ceremony. This aligns with the interview results from teachers and tenth-grade students, which show that teachers have not yet provided information or knowledge about local wisdom in biology lessons.

Students can be motivated and can understand material concepts well when the material is presented with visual aids such as images, videos, and technology-based tools. A teacher's skill in designing and presenting multimedia, including text, images, animations, audio, and video, that aligns with curriculum goals can support the achievement of student learning outcomes (Suwandi et al., 2023). Research by Elvianasti et al. (2023) shows that teachers have difficulty integrating ethnoscience into science learning. The challenge lies in converting local wisdom and potential content into a scientific, scholarly form. Local wisdom can be integrated into scientific knowledge, especially biology, by using a cultural context that is close to students' lives (Zidny & Eilks, 2020). Through an ethnoscience approach, students are taught to reconstruct a community's traditional knowledge into a scientific form that relates to the subject matter (Suprapto et al., 2021).

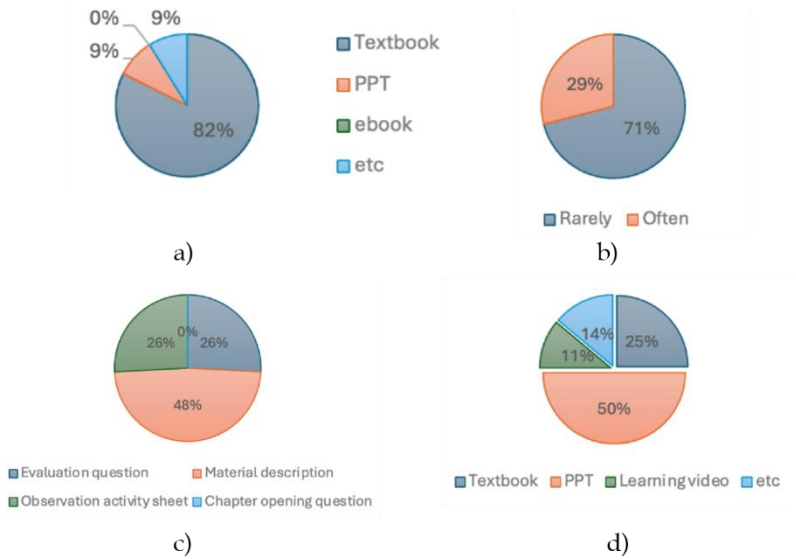
Regarding their knowledge of ESD and the SDGs, both teachers and students were unfamiliar with the concepts of ESD and the SDGs. Consequently, teachers did not understand the urgency of integrating ESD into biology lessons. ESD is an integral part of SDG 4, which focuses on quality education. This goal serves as a crucial foundation for achieving the other SDGs (Widodo et al., 2023). ESD can help students develop the ability

to make wise decisions and act responsibly to preserve the environment, support economic stability, and realize social justice for both current and future generations, while upholding cultural diversity (UNESCO, 2018). Intercultural learning can effectively integrate the concepts of the SDGs (Zidny et al., 2020).

3. Teaching Material Analysis

The results of the teacher interviews show that Teacher A has used teaching materials such as student worksheets, textbooks from brand X, and a digital bookmaker. Teacher B uses textbooks from both brand X and brand Y. Student learning outcomes with these materials were found to be quite good. Regarding the challenges or obstacles in using these teaching materials, Teacher A mentioned a lack of supporting school facilities and infrastructure. At the same time, Teacher B stated that student motivation tends to be low when using printed textbooks. Teachers are expected to select learning resources that align with learning objectives and are practical, effective, and easy to use (Samsinar, 2019). Teaching materials are essential to the learning process. Instructional materials play a crucial role in the learning process by enhancing students' learning outcomes (Asrizal et al., 2018).

Based on interview data from tenth-grade students at two schools, most students said their teachers used textbooks and PPTs. This finding aligns with the results of the teacher interviews. However, the textbooks were borrowed from the library, with one book shared between two students, so most students could not take them home. This affects how students review biology topics; they usually rely on their notebooks or use educational videos on digital platforms like YouTube. When asked about the format of learning resources, most students preferred digital books, such as e-books or e-modules. Their reasons included the ability to access information online and that they are more engaging, less boring, practical, and easier to understand. The advantages of e-modules over textbooks are that they are more interactive, can be tailored to individual student needs and learning pace, and are accessible via various devices like PCs, tablets, or mobile phones (Mulder, 2017). **Figure 2** presents the results of the eleventh-grade student questionnaire analysis on the teaching material aspect.



Note:

a) Teaching materials currently used by teacher
b) Student's experience completing evaluation questions in the textbook
c) Textbook features that are most effective in helping students understand the material
d) Learning materials that can effectively support biology lessons

Figure 2. Students' questionnaire answers about teaching materials

Based on the analysis of the eleventh-grade student questionnaire, the most frequently used material is the textbook, followed by occasional use of PPTs, and rare use of educational videos. This finding aligns with the results of the tenth-grade student interviews. When asked whether they complete the practice questions in the textbook, only a small number of students reported completing them frequently. Regarding textbook features that help students understand the material, most students chose material descriptions as the feature that best supports their grasp of concepts. When asked about the most effective types of teaching materials for biology, most students chose PPTs, while others selected printed books, some chose educational videos, and a few chose practical work. **Figure 3** explains the reasons for students' preferences for these various types of teaching materials or resources**.**

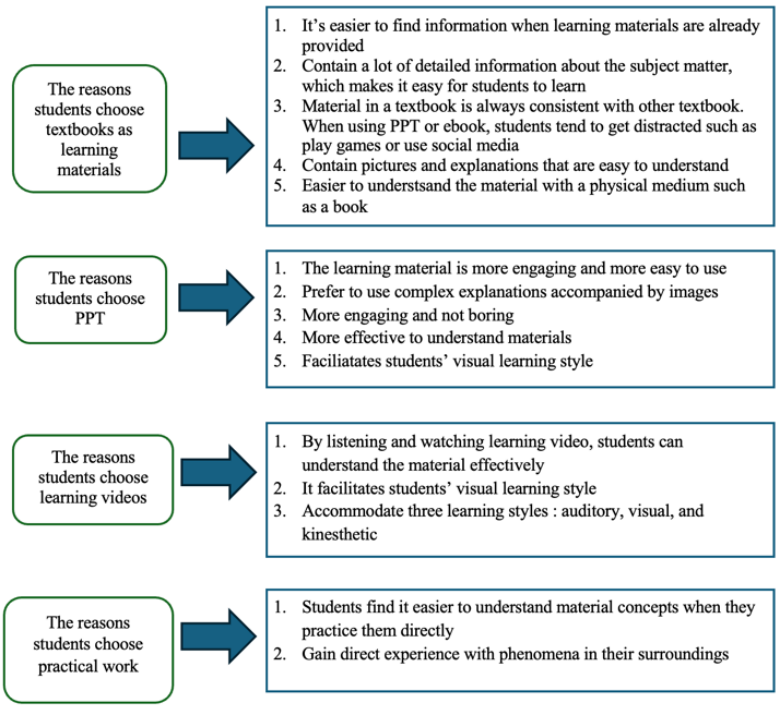


Figure 3. Learning materials that can effectively support biology lessons

In addition to conducting interviews with teachers, interviewing tenth-grade students, and distributing questionnaires to eleventh-grade students, data for the teaching materials analysis were also collected by analyzing the two textbooks currently used by teachers in Pasuruan. Based on the analysis of the textbooks used by teachers as learning resources, two books were identified, each with its own characteristics. **Book X** tends to focus on detailed material descriptions, supplemented with features that help students grasp concepts. It incorporates contextual issues, although not extensively, and lacks content on local wisdom or potential. It also does not explicitly facilitate students' understanding of the SDGs. This book includes some visual aids and supporting media integrated with the internet. It also contains evaluation questions that train students' critical thinking skills and follow the minimum competency assessment model of the *Merdeka* curriculum.

Book Y, on the other hand, focuses more on student activities, such as projects, observations, or independent exploration of concepts, resulting in a very limited description of the material, with a chapter spanning only seven pages. This book includes contextual phenomena or issues and incorporates the SDGs more explicitly than Book A, although not to its full potential. It does not contain visual aids or supporting media integrated with the internet. The Pancasila Student Profile is not explicitly mentioned in this book. Complete teaching materials allow students to learn competencies and learning objectives gradually and systematically, enabling them to master the competencies

thoroughly (Zainul et al., 2018). Reiser (2003) states that teaching materials serve as a learning resource for both students and educators, become a main reference for learning content, and convey a deep understanding of the basic characteristics of science education and how to develop knowledge. Teaching materials also serve as a foundation for teachers to design their teaching strategies, especially in science subjects (Yenni et al., 2017). Using teaching materials in the learning process is important for improving students' cognitive, skill, and affective aspects (Abidin, 2014).

Based on the empirical data from previous studies, integrating local wisdom in science learning yields positive responses and outcomes in enhancing the quality of learning across cognitive, affective, and psychomotor aspects. Science teachers can observe local cultures and phenomena surrounding students to serve as instructional sources linked to scientific concepts. Moreover, local wisdom content can be integrated with Higher Order Thinking Skills (HOTS), such as critical thinking, creative thinking, and problem solving. Additionally, to ensure learning remains relevant to contemporary challenges, teachers can align with ESD. This approach trains students to observe, analyze, and solve everyday problems, preparing them to become future agents of change.

Pasuruan has local potential in the form of the Bromo Tengger Semeru National Park and the local wisdom of the Tengger tribe, which has the potential to be implemented in biology or science lessons. Integrating local wisdom and ESD content in biology learning is still needed in high schools in the Pasuruan area. This study is limited to educational units within the Regency of Pasuruan. Nevertheless, it remains relevant as a reference for neighboring schools or areas that share similar characteristics and cultural contexts.

Conclusion

Based on the identification and analysis of the need to integrate local wisdom and ESD content in biology learning, three key aspects were identified: curriculum analysis, learning analysis, and teaching material analysis. The findings revealed three significant gaps: 1) Local wisdom being part of the Pancasila Student Profile in the Merdeka curriculum, and SDGs being included in the learning outcomes (CP) for Phase E of high school, 2) Pasuruan has local potential in the form of the Bromo Tengger Semeru National Park and the local wisdom of the Tengger tribe, which has the potential to be implemented in biology lessons, 3) Existing textbooks are insufficient in availability, lack of local wisdom content, present SDGs superficially, and do not leverage digital technology to support conceptual understanding. These findings carry significant implications for biology education in culturally and ecologically rich regions. Contextualizing biology learning through local wisdom not only strengthens students' cultural identity but also fosters sustainability-oriented thinking aligned with ESD goals. Therefore, future research should focus on designing and empirically validating a local wisdom- and ESD-based learning resource to address the identified gaps and improve the quality of biology education in the Pasuruan area or regions with similar characteristics.

Generative AI Disclosure

The use of artificial intelligence in this manuscript is limited to language translation and editing to improve readability, without affecting the scientific substance, data analysis, or research interpretation.

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