

DEVELOPMENT OF A HOLISTIC STEM PRACTICUM KIT INTEGRATING LOCAL WISDOM FOR RENEWABLE ENERGY LEARNING: A SYSTEMATIC REVIEW (2020–2025)

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ABSTRACT

21st century science education requires the integration of critical thinking skills and environmental awareness; however, the availability of contextual practicum media that supports this integration remains limited. This study aims to analyze trends, patterns, and research gaps in the literature published between 2020 and 2025 regarding the development of STEM-based practicum kits integrated with local wisdom on renewable energy materials. A Systematic Literature Review (SLR) method was employed using the PRISMA protocol and VOSviewer bibliometric analysis on the Scopus database. The inclusion criteria covered peer-reviewed journal articles and conference proceedings written in English, published between 2020–2025, and reporting empirical or development studies related to STEM learning media or practicum kits in science education. Studies not related to renewable energy learning contexts, review-only papers without empirical discussion, and non-English publications were excluded. Based on this process, 13 relevant articles were selected and synthesized. The results indicate that the development of learning media is still dominated by digital modules compared to physical practicum kits. In addition, the literature shows a saturation of studies focusing on the cognitive aspect, particularly critical thinking, while research addressing environmental awareness remains limited. Network visualization further confirms that environmental education topics remain marginal and are not yet strongly integrated with mainstream STEM approaches. These findings highlight a significant research gap and emphasize the need to develop a holistic practicum instrument capable of simultaneously strengthening scientific reasoning and ecological character, thereby supporting culturally relevant renewable energy learning innovations.

Keywords: Practicum kit; STEM; Local wisdom

INTRODUCTION

Science education in the 21st century faces the urgent challenge of equipping students not only with conceptual understanding, but also with high-level thinking skills and environmental sustainability awareness to tackle global issues such as the energy crisis. The current phenomenon shows that science learning is often still theoretical and separate from the real-life context of students, resulting in low energy literacy and a lack of students' emotional involvement in environmental issues (Noerazizah, 2025; Paristiowati et al., 2025). From a cognitive–affective

learning perspective, critical thinking represents the cognitive dimension that enables students to analyze scientific problems, while environmental awareness reflects the affective dimension that shapes attitudes and responsibility toward environmental sustainability. The integration of these two dimensions is considered essential because cognitive understanding alone is often insufficient to encourage pro-environmental behavior in real life. To answer this challenge, the integration of Science, Technology, Engineering, and Mathematics (STEM) approaches with local wisdom

(ethnoscience) is seen as a strategic solution because it is able to bridge modern scientific knowledge with relevant local cultural values (Latip & Kadarohman, 2024). However, although the STEM approach is known to be effective in improving critical thinking skills (Irvaniyah & Ali, 2025), implementation in the field still faces obstacles, especially related to the availability of adequate learning media such as practicum kits that are able to visualize abstract concepts of renewable energy in a contextual manner (Rahmayanti & Rahardjo, 2024). Therefore, an in-depth study of the development of learning tools that combine STEM elements, local wisdom, and renewable energy materials is very crucial to be carried out.

Research trends in the period 2020–2025 show a significant surge in the development of ethnoscience-based and STEM-based teaching materials, but the majority of these studies are still partial and fixated on certain geographical contexts or certain types of media such as electronic modules. For example, research on the development of ethnoscience-based e-modules on renewable energy materials in Lake Ranau has been proven to increase students' literacy (Rohman *et al.*, 2024), as well as the development of bio-battery practicum kits from fruit peel waste that effectively improve practicum skills (Ningrum & Prasetyo, 2025). In addition, another study found that the integration of STEM-PjBL with seaweed ethnoscience in coastal areas is able to train creativity, but its application by teachers is still low due to a lack of practical guidance (Putri *et al.*, 2025). Although many empirical studies report local success, there are inconsistencies and gaps in the literature on how to design an ideal practicum kit that can integrate the engineering complexity of

STEM with local cultural values in a balanced manner to target two outputs at once: critical thinking and environmental awareness (Agusty *et al.*, 2021; Ursula *et al.*, 2024; Winaryati *et al.*, 2025). Most previous literature reviews tend to focus separately, either on pure STEM (Sihombing *et al.*, 2025) or in ethnoscience in general (Live) *et al.*, 2025), without synthesizing specifically in the practicum kit media on the topic of renewable energy.

Therefore, research using the Systematic Literature Review (SLR) method is very important to fill this gap by synthesizing fragmented findings from various recent developmental and experimental studies. In contrast to field research that is limited to a single location, the SLR approach allows for the identification of broader patterns related to the design characteristics, effectiveness, and challenges of implementing STEM-Ethnoscience-based practicum kits in various demographic contexts (Matindike & Ramdhany, 2025). The focus on practicum kits is particularly relevant because hands-on learning media have been widely reported to facilitate conceptual understanding, strengthen scientific reasoning, and improve students' engagement with environmental issues compared to purely theoretical or digital learning approaches. Through direct experimentation and manipulation of learning tools, students can observe energy conversion processes more concretely, which supports both conceptual transfer and the development of environmental attitudes. The results of this study are expected to make a theoretical contribution to the science education literature as well as practical recommendations for educators and policy makers in designing effective

learning instruments to produce a critical and environmentally conscious generation.

This Systematic Literature Review (SLR) research aims to comprehensively analyze and synthesize the latest scientific literature (2020–2025) regarding the development of STEM-based practicum kits that are integrated with local wisdom on renewable energy materials. This study is specifically directed to identify significant research patterns, trends, and gaps from previous studies in order to map the effectiveness of the integration of these approaches in improving students' critical thinking skills and environmental awareness. Unlike previous reviews that generally focus separately on STEM implementation or ethnoscience-based learning, this study provides a more integrated synthesis by specifically examining the design characteristics, educational outcomes, and research gaps related to STEM-based practicum kits in renewable energy learning contexts. By highlighting the imbalance between cognitive outcomes and affective environmental outcomes in the existing literature, this study contributes to clarifying the direction of future research on the development of holistic learning instruments that simultaneously address scientific reasoning and ecological awareness. Furthermore, this research aims to produce an in-depth understanding that can clarify the direction of development of science education theory, methodology, and practice, as well as make a solid conceptual contribution to the design of future learning instruments that are culturally relevant and responsive to sustainability issues.

METHOD

This study uses a Systematic Literature Review (SLR) design by adopting the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol to ensure the transparency, validity, and replicability of the study. This approach was chosen to identify, evaluate, and synthesize high-quality literature related to the development of STEM-based practicum kits and local wisdom. The PRISMA methodological framework is used to map the flow of article selection starting from initial identification, screening, feasibility, to inclusion of the final document. The use of these standards is crucial in minimizing selection bias and ensuring that the data obtained is relevant to the development of renewable energy learning instruments (Page et al., 2021; Snyder, 2019). The following is the flow of the PRISMA diagram used in this study:

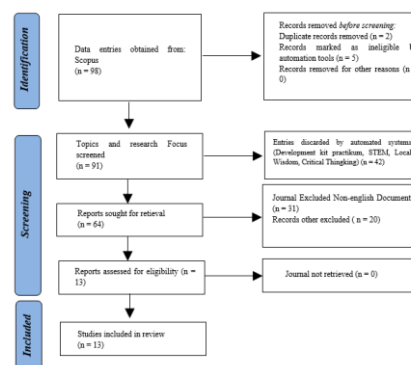


Figure 1. Article Selection Prism Diagram

A comprehensive literature search was conducted on the Scopus database, which was selected because of its reputation as a multidisciplinary scientific database with extensive citation coverage and strict indexing standards. The search was limited to publications from 2020 to 2025 to capture the most recent developments in educational technology and environmental education research. The

search strategy employed a combination of specific keywords and Boolean operators to retrieve relevant documents related to STEM-based practicum kits, local wisdom, renewable energy learning, and learning outcomes such as critical thinking and environmental awareness.

To ensure the relevance and quality of the selected studies, several inclusion and exclusion criteria were applied. The inclusion criteria consisted of: (1) peer-reviewed journal articles and conference proceedings indexed in Scopus, (2) studies published in English between 2020 and 2025, (3) empirical or development-based research related to STEM learning media, practicum kits, or laboratory-based instructional tools, and (4) studies involving school or university students as participants. The exclusion criteria included: (1) articles not related to renewable energy learning contexts, (2) purely theoretical papers or opinion articles without empirical data, (3) duplicate records, and (4) publications not written in English. These criteria were applied to ensure that only relevant and high-quality studies were included in the synthesis.

The Boolean queries used for the search are as follows:

TITLE-ABS-KEY ("*Practicum Kit*" OR "*Science Kit*" OR "*Laboratory Kit*" OR "*Instructional Media*") AND TITLE-ABS-KEY ("*STEM*" OR "*Science Technology Engineering Mathematics*" OR "*Local Wisdom*" OR "*Ethnoscience*" OR "*Indigenous Knowledge*") AND TITLE-ABS-KEY ("*Renewable Energy*" OR "*Green Energy*" OR "*Alternative Energy*" OR "*Energy Sustainability*") AND TITLE-ABS-

KEY ("*Critical Thinking*" OR "*Higher Order Thinking*" OR "*Environmental Awareness*" OR "*Ecological Literacy*") AND PUBYEAR > 2019 AND PUBYEAR < 2026

After the search process, data extraction was carried out using Mendeley's reference management software. The metadata of the retrieved articles were exported in RIS (Research Information Systems) format to facilitate organizing, duplicate detection, and citation management. The article selection process followed several stages, including identification, screening, eligibility assessment, and final inclusion based on the PRISMA framework.

The screening process was conducted independently by two reviewers to reduce selection bias. Initially, titles and abstracts were screened to identify potentially relevant studies. Articles that met the preliminary criteria were then evaluated through full-text review to confirm whether they contained empirical data on the effectiveness of practicum kits in improving students' critical thinking skills and environmental awareness. In cases where disagreements occurred between reviewers, discussions were conducted until a consensus was reached. To ensure the reliability of the selection process, inter-rater agreement was assessed using Cohen's kappa coefficient. The use of Mendeley ensured bibliographic accuracy and improved efficiency in managing the research database (Donthu et al., 2021).

The data analysis stage is focused on bibliometric mapping and content analysis to test the validity and reliability of the findings. Bibliometric analysis was carried out with the help of VOSviewer software to

visualize keyword networks (keyword co-occurrence), trends in author collaboration, and linkages between topics. These analysis parameters are used to validate the consistency of the research theme and identify research gaps in the existing literature. In addition, the reliability of qualitative data is maintained through triangulation of sources from various reputable journal articles that have passed the selection, resulting in a solid synthesis of STEM integration and local wisdom in energy learning (Eck & Waltman, 2010; Zupic & Ater, 2015).

RESULTS AND DISCUSSION

Based on Figure 2, the distribution of literature is dominated by Science Education Journals (38.5%) and Conference Proceedings (30.8%), which indicates that the current STEM integration discourse is very massively disseminated through specific educational forums and early publication of conferences. However, content analysis reveals significant gaps where the majority of existing studies are still dominated by development methods (*R&D*) and quasi-experiments that focus partially on digital modules or general teaching tools, and tend to emphasize only the improvement of critical thinking skills. This study fills this gap by using the *Systematic Literature Review* (SLR) method to comprehensively synthesize the effectiveness of *physical practicum kits* that specifically integrate STEM approaches and local wisdom on renewable energy materials, a combination of variables that have not been widely explored to simultaneously increase environmental awareness with cognitive ability.

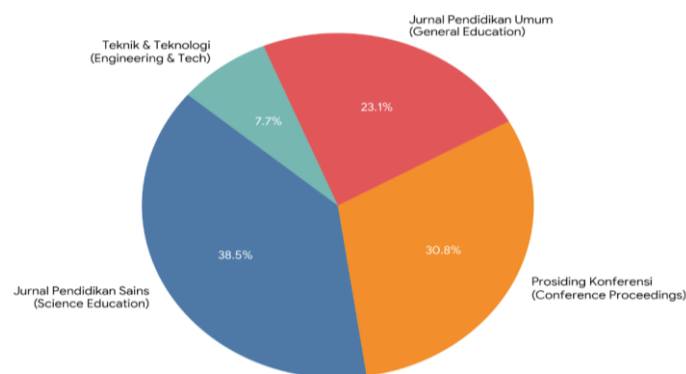


Figure 2. Distribution of Articles Based on the Scope of the Journal

Based on the visualization of the affiliation diagram, the research map shows a fragmented distribution pattern where Surabaya State University and Lambung Mangkurat University dominate quantitatively with a contribution of 15.4% each (2 articles), while the remaining 69.2% is a single contribution spread across various institutions across continents (Europe, Asia Pacific, and Southeast Asia). This data indicates a *collaboration gap* and topic discontinuity, where the development of STEM practicum kits is often sporadically carried out as a local project without strong inter-institutional integration. Therefore, this *Systematic Literature Review* (SLR) research is here to bridge this gap by synthesizing the scattered findings into a complete conceptual framework, linking technical innovations from international research with cultural approaches (local wisdom) from national research to produce a more comprehensive renewable energy learning model.

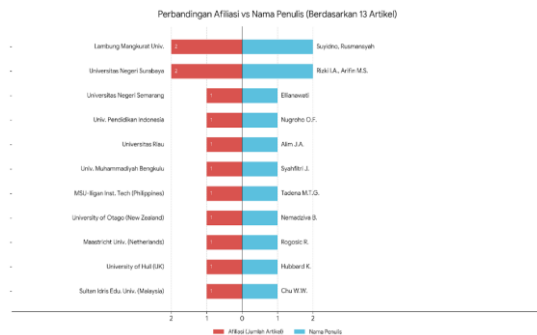


Figure 3. Comparison of Affiliates with Author Names

The visualization of the butterfly diagram above shows a sharp asymmetry between the factual conditions of the publication (left side) and the potential for research novelty (right side). On the left side, it was identified that there was a saturation of research on the variable of critical thinking skills that dominated the literature (6 articles). On the other hand, there is a significant scarcity of data on environmental awareness variables that are only discussed in 2 articles, as well as empirical gaps (zero articles) in studies that integrate both variables simultaneously in one practicum instrument.

This condition confirms the *state-of-the-art* position of the title of this study. *The research gap* lies in the inequality of academic focus which has been too heavy on the cognitive aspect (critical thinking) and tends to ignore the integration of affective aspects (environmental awareness) at the same time. With the highest urgency value (5 scale) on the right side of the diagram, this study has a strong novelty value because it serves as a bridge that fills the void, offering a holistic learning solution that not only hones students' science logic through STEM, but also instills the character of caring for the environment through an approach of local

wisdom that has not been touched by previous researchers.

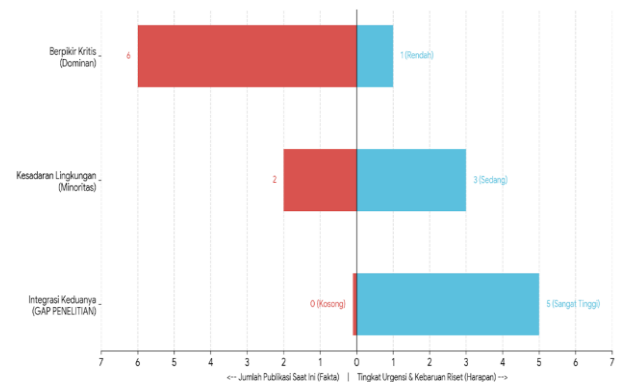


Figure 4. Gap Map (GAP) of Research Quantity with Potential Novelty

The following is an SLR Synthesis Matrix compiled to answer the purpose of this study. This matrix maps the findings of 13 selected articles, identifies patterns and trends, and emphasizes the research gaps that underlie the urgency of your research title.

Table 1. Synthesis Matrix Systematic Literature Review (SLR)

Analisis Aspect	Findings from the Literature (13 Articles)	Gap Identification (Research Gap)	Contributions/Implications for This Research
1. Trends in Media & Instrument Types	<ul style="list-style-type: none"> Dominance of Non-Physical Kits: Most of the development is in the form of teaching modules, e-modules, or 	The lack of development of specific "Physical Practical Kits"	This research fills the gap by developing concrete products (Physical)

	learning models (e.g., Rusmansyah et al., 2022; Alim et al., 2025).	design ed for Rene wable Energy materi als. Most renew able energy media are still digital (AR/AI) or textual (modu le) based.	cal Kits), not just concep tual teachin g tools, thus facilitat ing <i>a more real</i> hands-on experie nce.	Muntahana h, 2024).	ering design in the Rene wable Energy STEM Kit.	(ethnos cience) , not just a materia l attach ment.	
	• Separate Kit: Physical practicum kits are available (e.g.: <i>Science Kit</i> by Rogosic et al. 2021; <i>Smartphon e Kit</i> by Chu et al. 2023), but often general or non-energy specific topics (sound, static electricity).						
2.	• Partial Integratio n: Studies tend to focus on STEM only (Rizki & Suprpto, 2024) or Local Wisdom only in the module (Syahfitri &	There has not been a cohesi ve integra tion model where Local Wisdo m is the basis for engine	This researc h offers a novelty of method s by making local wisdo m the foundat ion of tool design	3.	• Cognitive Dominanc e: The majority of research focuses solely on improving Critical Thinking/ Creative (Ellianawat i et al., 2025; Suyidno et al., 2025).	" The Missin g Link " : The absenc e of studies measu ring the simult aneous impact on Critic al Think ing AND Envir onme ntal Aware	This researc h is a pioneer in testing the dual <i>impact effectiv eness</i> of instrum ents on cogniti ve compet ence (critica l) and sustain ability charact er

	appears as a separate topic (Arifin <i>et al.</i> , 2025; Tadena & Salic-Hairulla, 2021) and is rarely associated with high-level thinking abilities.	ness. The existing literature treats the two as separate variables.	(environmental awareness) simultaneously.
4. Content of Renewable Energy Materials	<ul style="list-style-type: none"> • General Discussion: Renewable energy materials are often discussed extensively or theoretically in modules. • Limited Specific: Few use kits to model specific renewable energy technologies relevant to local potential. 	Lack of practical instruments that visualize the conversion of renewable energy in real terms using local materials/con texts.	Directs kit design to simulate concrete energy solutions relevant to environmental issues around students.

The visualization of the VOSviewer network shows an uneven linear distribution pattern, where the "development" and "critical thinking skill" clusters on the left side dominate as the

main stream of research, strongly connected through the "STEM approach" on the middle side as the main methodological intervention. In contrast, the "environmental education" node at the far right looks marginal with a smaller node size and loose connectivity from the development core, indicating that the environmental aspect is still treated as a secondary output rather than the cognitive aspect. This network structure graphically validates the research *gap* you raise, emphasizing the need for new research that is able to pull these environmental gap variables from a peripheral position to a fully integrated central focus in the development of STEM-based practicum kits.

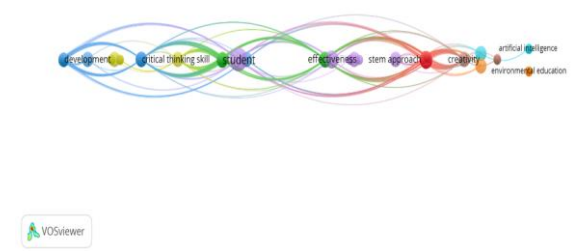


Figure 5. *Network Visualization*

The visualization of the VOSviewer overlay reveals a sharp temporal gap, where the topics of "STEM approach" and "creativity" emerge as the most up-to-date research trends (2024–2025) marked in yellow, while "environmental education" is left behind as the old discourse (2022) with a dark blue color that begins to fade from the main focus. This condition indicates that the current trend of STEM innovation tends to run alone leaving environmental issues, so this research has a high urgency of novelty to "rejuvenate" the topic of environmental awareness by pulling it back into the *mainstream* of modern STEM approaches, ensuring that the advancement of

educational technology goes hand in hand with the strengthening of ecological characters relevant to today's sustainability challenges.

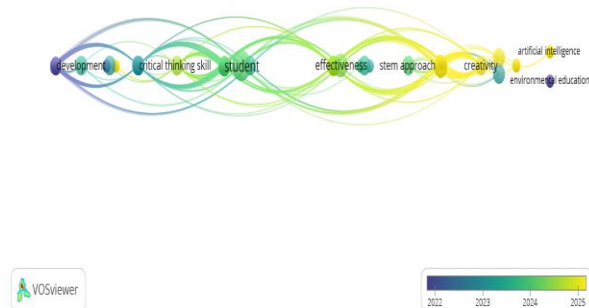


Figure 6. *Overlay Visualization*

Based on the Density visualization, the literature map shows a very saturated concentration of research (high density) on three bright yellow hot spots, namely "development", "student", and "STEM approach", which indicates that the main focus of researchers has been on the development of technical learning tools for students. In contrast, the keywords "environmental education" and "artificial intelligence" appear in the low-density zone that almost blends with the background, indicating a lack of in-depth exploration in these areas. Several studies demonstrate that the integration of local wisdom in STEM learning has been implemented through culturally contextual learning designs, such as the incorporation of Sasirangan cultural practices in science learning activities and the use of locally available materials to construct simple experimental tools (Rusmansyah et al., 2022). These approaches allow the design of practicum activities that reflect local cultural knowledge, for example by adapting traditional materials, environmental practices, or local energy resources into engineering-based learning tasks. Empirical evaluations in these studies

show that culturally contextualized learning designs can increase students' engagement, contextual understanding of scientific concepts, and awareness of environmental sustainability. Therefore, this visual inequality further validates the research gap highlighted in this study, where the environmental awareness variable remains marginal and insufficiently integrated into mainstream STEM-based practicum development. This study therefore attempts to address this gap by emphasizing the integration of environmental awareness as a central component in the development of STEM-based practicum kits that incorporate local wisdom.

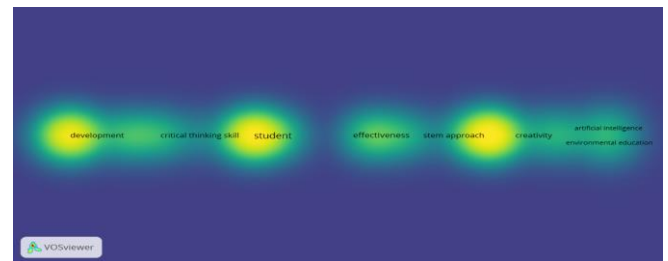


Figure 7. *Density Visualization*

The trend of developing learning media in the period 2020–2025 shows the polarization between digital innovation and physical devices, where the integration of local wisdom is starting to become an emerging focus. A number of studies focus on the development of module-based teaching tools and digital technologies, such as Suyidno et al. (2025) who integrate Augmented Reality and Artificial Intelligence, Alim et al. (2025) who develop STEM-based e-modules using the MIKiR model, and Syahfitri & Muntahanah (2024) who compile interactive modules based on local wisdom. Several studies also report the development of physical practicum kits (hands-on learning), including the use of smartphones as measurement tools in STEM experiments

by Chu et al. (2023), the Modular Science Kit designed for primary and secondary schools by Rogosic et al. (2021), and independent at-home practicum kits developed by Hubbard et al. (2025).

However, an examination of the methodological quality of the included studies indicates that many of these findings are derived from small-scale experimental or development studies conducted within limited classroom contexts. Only a few studies employ rigorous quasi-experimental designs with larger samples and validated assessment instruments. This suggests that although the reported effectiveness of these learning tools is promising, the overall strength of evidence remains moderate, and caution is needed when generalizing the results across broader educational contexts.

Local wisdom-based approaches are specifically explored by Rusmansyah et al. (2022) through the development of learning devices based on Sasirangan cultural practices, where traditional patterns and dyeing processes are used as contextual examples in scientific problem-solving activities. Similarly, You et al. (2023) and Nemasziva et al. (2025) emphasize contextual STEM learning designs that incorporate indigenous community knowledge and locally available materials to address learning challenges in rural schools. These examples demonstrate how cultural practices can influence the design of practicum activities, such as the selection of local materials, contextual problem scenarios, and culturally relevant engineering tasks, thereby strengthening the connection between scientific concepts and students' everyday experiences.

Judging from external learning outcomes, the majority of studies place higher-order thinking skills as the primary

dependent variable, while the integration of environmental awareness remains relatively limited. Improvements in critical and creative thinking skills are the dominant findings in studies such as Rizki & Suprpto (2024), who implement Project-Oriented Problem-Based Learning, and Ellianawati et al. (2025), who apply STEAM-based collaborative learning in renewable energy contexts. In contrast, the environmental awareness variable has not been explored as intensively as the cognitive aspect. Only a few studies explicitly emphasize environmental literacy as a primary learning outcome, such as Arifin et al. (2025), who utilize waste plastic bottles to construct electroscope tools as part of climate literacy learning, and Tadena & Salic-Hairulla (2021), who promote locally based environmental education. These findings confirm the existence of a research gap, where the development of practicum kits designed to simultaneously improve critical thinking and environmental awareness, particularly in renewable energy learning contexts remains very limited.

Despite these findings, several limitations should be acknowledged when interpreting the results of this bibliometric and literature synthesis. First, the analysis relies solely on the Scopus database, which may introduce database bias because relevant studies indexed in other databases such as Web of Science, ERIC, or Google Scholar may not have been captured. Second, the inclusion criteria restricted the analysis to English-language publications, which may have excluded potentially relevant research published in other languages, particularly studies reporting local educational innovations. Third, bibliometric mapping primarily reflects publication trends rather than the full

diversity of educational practices implemented in different regions. These limitations suggest that the generalization of the findings should be interpreted cautiously, and future studies may expand the database sources and language coverage to obtain a more comprehensive representation of global research trends in STEM-based practicum kits and local wisdom integration.

CONCLUSION

This Systematic Literature Review (SLR) study concludes that the trend of developing learning media on renewable energy materials in the period 2020–2025 is still dominated by digital module-based devices and technology (AR/AI), with a significant deficit in the development of physical practicum kits that substantially integrate local wisdom. The literature synthesis reveals an asymmetrical pattern in learning outcomes, where the research focus is very heavy on improving critical thinking skills (cognitive aspects) that reach saturation points, while the environmental awareness aspect (affective aspect) is still marginalized and rarely used as an integrated main variable.

Methodologically, it was found that the integration of STEM and ethnoscience approaches is often still partial, where local wisdom is only placed as a material context and has not been used as the basis for the engineering design of practicum tools. Based on these findings, several directions for future research are recommended. First, future studies should develop and test physical practicum kit prototypes based on local wisdom that explicitly integrate STEM principles in renewable energy learning. Second, further research should validate the construct and measurement instruments used to assess environmental

awareness to ensure reliable evaluation of affective learning outcomes. Third, empirical studies are needed to evaluate the implementation and effectiveness of such practicum kits in different educational contexts, including diverse school environments and student populations. Through these directions, future research can strengthen the development of holistic learning instruments that simultaneously foster scientific reasoning and environmental responsibility, contributing to more culturally relevant and sustainable science education practices.

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