Journal of Current Studies in SDGs
Homepage : https://journal.i-ros.org/index.php/JOCSIS
Email : jocsis@i-ros.org

e-ISSN 3089-7564
Vol.2, No.1, March 2026

Bridging Local Culture and Scientific Literacy through the I-BATARA Learning Model: Validation and Implications for SDG 4 Quality Education

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DOI : https://doi.org/10.63230/jocsis.2.1.148

Sections Info

Article history:
Submitted: May 17, 2025
Final Revised: May 28, 2025
Accepted: May 29, 2025
First Available Online: June 17, 2026
Publication Date: June 27, 2026

Keywords:
Batik Tanjung Bumi;
Education;
Learning model;
Local Culture;
Scientific Literacy.

ABSTRACT

Objective: *To validate the I-BATARA learning model. The I-BATARA learning model, designed by integrating local cultural contexts, batik Tanjung Bumi, and scientific concepts, aims to improve science literacy.* ***Method:*** *Educational development research was used as the research design. Validation of the I-BATARA leaning model and instructional package involves two criteria: content validation and construct validation. Three experts in pedagogy, science content, and learning assessment validated the I-BATARA learning model and instructional package.* ***Results:*** *The research findings and data analysis indicated that the I-BATARA learning model has consistently yielded relevant outcomes. The I-BATARA model has met strict validity and reliability standards (with an agreement percentage >75%).* ***Novelty:*** *Validated learning support components include lesson plans, student textbooks, student worksheets, and scientific literacy tests. The I-BATARA learning model can be applied to foster students' scientific literacy through local cultural contexts. The model is suitable for meaningful science learning and for developing students' social skills, while offering practical implications for SDG 4 (Quality Education) by promoting culturally relevant, context-based scientific literacy instruction.*

INTRODUCTION

In the context of the rapidly expanding and increasingly complex information landscape of the 21st century, scientific literacy, as one of the foundational literacies, has emerged as a competency that requires early and systematic development in formal education (González & Reiss, 2023; Puspitarini et al., 2025). Students who have scientific literacy can act as agents of change and develop innovative solutions to the complex problems facing the world today (Mulyono et al., 2024). Students are confident in dealing with various situations and making decisions (Al Sultan et al., 2021) and have ideas for solutions to issues related to science and technology (Budiarti & Tanta, 2021)

The results of the 2022 PISA assessment show that Indonesia ranked 67th out of 81 participating countries in science literacy, with a score of 383. Low scientific literacy arises from multiple factors, including students' inability to apply procedural knowledge to assess scientific explanations, thereby hindering their data interpretation and conclusion-drawing skills (Sholahuddin et al., 2021) a lack of connection between scientific concepts and pupils' everyday lives (Childs & Hayes, 2015) because the learning process in the classroom is not yet fully contextual, due to teachers still finding it difficult to link context to concepts (El Arbid & Tairab, 2020). Furthermore, students still think in concrete terms and therefore require interventions and resources to facilitate abstract thinking (Erman & Wakhidah, 2023).

A familiar context can help pupils learn science by making abstract concepts more concrete, boosting their motivation and sense of ownership, and fostering deep curiosity about the local knowledge being studied. Context-based learning is important for linking scientific concepts to the real world, thereby increasing students' interest and helping them understand the material more meaningfully (Güth & Vorst, 2024; Saragih et al., 2023), and for enhancing students' intrinsic motivation (Meulenbroeks et al., 2024). Local wisdom provides a culturally relevant context that aligns with community values and learning practices

Science education that integrates local wisdom and cultural contexts has an impact on learning activities, including cognitive skills such as improved problem-solving, communication, and collaboration (Rahmawati et al., 2020), scientific literacy (Astawan et al., 2025), critical thinking skills (Prayogi et al., 2023), and conservation and entrepreneurial character in students (Sudarmin et al., 2023). A learning process that is responsive to culture can support meaningful learning by connecting students' prior knowledge (Hastuti et al., 2019; Smith et al., 2022). Various models have been implemented to carry out learning that systematically integrates local cultural contexts into learning components, including the Science Integrated Learning Model (Parmin et al., 2017), Ethno-STEM Integrated Project Learning Models (Sudarmin et al., 2024) and ethno-STEAM (Sumarni et al., 2025), as well as learning that utilises local wisdom contexts, such as batik (Amalia & Sunarya, 2020; Muhakimah & Arfinanti, 2024; Nikmah et al., 2023; Pertiwi & Sutapa, 2018), bull racing in Madura (Suliyanah et al., 2023; Suprapto et al., 2022) and pacu jalur in Riau (Zulirfan et al., 2023).

A cultural product that can be integrated into learning is batik Tanjung Bumi. The philosophical and symbolic value of the motifs, as well as the process of making Tanjung Bumi batik, can also be linked to the nature of science (Suminto, 2015). The content structure of the batik-making process at Tanjung Bumi is examined through scientific analysis, for example, the use of wax. Wax is composed of ester fatty acids and long-chain alcohol compounds (Malik & Ayu, 2016). The natural dye used in batik Tanjung Bumi is Indigofera tinctoria, which is widely used as a source of blue dye. This plant contains the glucoside indican (indoxyl-β-D-glucoside). After the plant is soaked in water, enzymatic hydrolysis converts indican into indoxyl (white tarum) and glucose. Indoxyl can be oxidized into a blue-coloured substance known as indigo (Rao et al., 2025). This potential has not yet been formally integrated into the design of structured, measurable science curricula. There is currently no learning model explicitly designed to integrate the context of Batik Tanjung Bumi to develop scientific literacy competencies holistically. An appropriate and effective teaching process is expected to enhance pupils' understanding of science concepts through the hand-drawn batik of Tanjung Bumi, Madura, and to develop scientific literacy. The inquiry model is a learning approach that incorporates constructivist elements. The inquiry model is characterized by active student participation, questioning, collaboration, investigation, and connection to the real world (Dah et al., 2024; Hinostroza et al., 2024). However, the implemented inquiry-based model does not integrate local wisdom into an explicit understanding of the concept. Therefore, a stage is needed to help students understand the context, thereby improving their scientific literacy.

Therefore, learning in the current era must be designed to improve students' scientific literacy (Sadler et al., 2016). The curriculum must include learning that fosters an understanding of scientific concepts, the use of evidence, and the development of critical thinking skills (Sjöström, 2025). Moreover, teachers need adequate training to facilitate learning that builds strong scientific literacy in students (Almutairi & Alangari, 2025). By prioritizing scientific literacy in education, we are not only preparing the next generation to solve complex challenges but also unlocking the vast potential of scientific knowledge and understanding.

The emphasis on strengthening scientific literacy is closely aligned with Sustainable Development Goal 4 (SDG 4), which seeks to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. Scientific literacy enables learners to engage critically with scientific information, make evidence-based decisions, and participate responsibly in addressing societal challenges. Therefore, developing culturally relevant learning models that foster scientific literacy from an early age represents an important educational strategy to support the realization of quality education.

In exploring the world of science, the inquiry-based learning model has emerged as one of the most effective strategies for improving students' scientific literacy (Alim et al., 2020; Putri et al., 2021). The inquiry model encourages students to become researchers actively engaged in exploration, discovery, and problem-solving (Großmann & Wilde, 2019). Through experiments, observations, and data analysis, students learn to scrutinize information and draw conclusions based on the available evidence. However, the successful implementation of the inquiry model in the classroom depends not only on its application (Erman et al., 2018) but also on students' ability to connect scientific concepts to everyday life. Without using real-world contexts, inquiry-based learning becomes irrelevant to students (Qamariyah et al., 2021).

Therefore, the implementation of the inquiry model needs to be linked to the local culture and knowledge of the pupils' area. By linking scientific concepts to local traditions, beliefs, and knowledge, pupils can gain a deeper and more relevant understanding. In inquiry-based learning, this is put into practice through observation and experimentation. The inquiry learning model has the characteristics: (1) active involvement, (2) questions as a leader, (3) critical involvement, (4) collaboration, (5) independence, and (6) connection to the real world (Dah et al., 2024; Radu et al., 2023)

However, the effective implementation of an inquiry-based learning model requires not only a deep understanding of science but also sensitivity to students' cultural context and local environment. Through the integration of local wisdom, science learning can become more meaningful and relevant, enriching the learning experience for all students. This study aims to develop a learning model that integrates the local wisdom of batik Tanjung Bumi, known as the I-BATARA model. The I-BATARA model (Inquiry Learning Model Based on Local Wisdom of Batik Tanjung Bumi Madura) is proposed as a new instructional framework that scaffolds the phases of scientific inquiry, cultural exploration, and contextual reflection. This model is designed with clear syntax, contextual supporting materials, and science literacy assessment instruments integrated into each stage of learning. The principle of integrating local wisdom into I-BATARA supports education for sustainable development; consequently, the validation instruments include expert assessments of cultural appreciation.

Before being widely implemented, every innovative learning model must undergo validation to ensure its theoretical and practical feasibility and potential effectiveness. Validation involves assessment by experts (science subject specialists, pedagogical experts, cultural experts, and education practitioners) of the following aspects: conceptual accuracy, syntactic appropriateness, clarity of steps, cultural safety, and the measurability of science literacy outcomes. The validation process also identifies the need for revisions before the model enters a larger-scale empirical trial phase.

Validating the I-BATARA model through expert judgment ensures its readiness as a tool for enhancing science literacy grounded in cultural context. This research focuses on the content and construct validity of the I-BATARA model, which provides a structured, adoptable science learning model that aligns with the Merdeka Curriculum paradigm and promotes the preservation of cultural heritage through a scientific, contextual educational approach.

RESEARCH METHOD

This type of research is classified as Educational Design Research (EDR) (Hemtasin et al., 2026; Mckenney & Reeves, 2025). EDR is used to design and develop specific products and to test the feasibility of products that meet the criteria of validity, practicality, and effectiveness (Branch, 2009). This study aims to develop a valid, practical, and effective I-BATARA model to improve students' science literacy. The validity of the I-BATARA model is assessed based on the model rationale, the scope of supporting theories, the model syntax, the social system, the reaction principle, the support system, and the learning impacts, which comprise instructional and accompanying impacts. The model's supporting tools include the lesson plan, student worksheets, student learning materials, and assessment instruments.

The validation stage was carried out by three experts in the fields of pedagogy, science content and assessment to validate the I-BATARA learning model book, learning tools and research instruments. Validation panel experts selected three complementary domains critical to the I-BATARA learning model, namely science education background, cultural studies, and instructional design. Validators were recruited through criterion-based purposive sampling. These validators possess extensive experience in their fields and hold the highest educational qualifications. Validation instruments are used to assess the product's suitability and quality on a scale of 1 to 4. The validator completes a validation form covering construct, content, and instrument validation; the validation results are then analyzed for validity in terms of mode and reliability using the percentage of agreement. Differences arising from the validation process are then discussed in a group discussion forum to reach a consensus. The steps of the research method are interpreted in Figure 1.

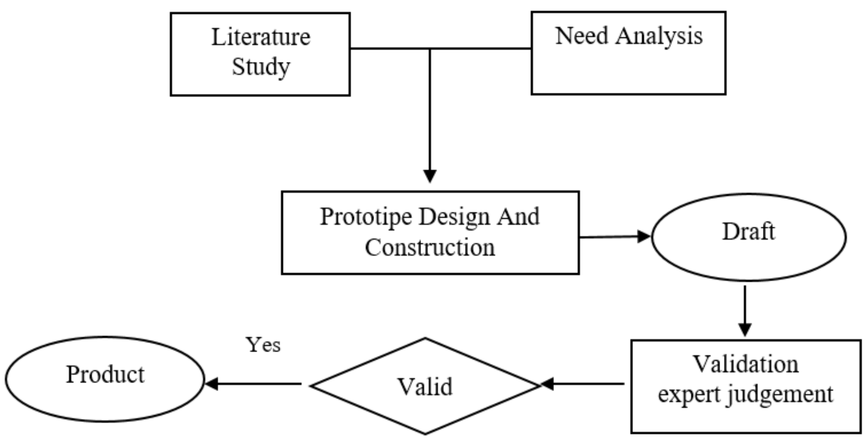

Figure 1. The steps of the research method

The data on the validation results for the model and learning materials were calculated from the mode scores for each indicator provided by three experts. The validity level was then determined using Table 1.

Table 1. Validation categorization criteria

Mode Score	Validity Criteria
1	Invalid
2	Less valid
3	Valid
4	Very valid

(Erman et al., 2022)

The reliability of the model validation instrument and supporting tools for the I-BATARA learning model was determined by calculating the level of agreement between observers. Validation results are reliable if the reliability value is ≥ 75% (Borich, 2017).

RESULTS AND DISCUSSION

Results

This research resulted in the development of the I-BATARA learning model, based on theoretical and empirical studies of inquiry-based learning, scaffolding, context-based learning, and local wisdom-based learning.

I-BATARA learning model components

Syntax I-BATARA learning model

The instructional syntax I-BATARA refers to a sequence of structured steps that must be followed in the learning process to achieve specific objectives. Details of the I-BATARA model syntax and activity descriptions are shown in Table 2.

Table 2. Details of the syntax and activity descriptions I-BATARA learning model

I-BATARA Syntax	Descriptions
Phase 1 *Scaffolding based inquiry*	Linking scientific concepts to the context of local wisdom. Scaffolding is used in conjunction with the IDEA strategy (identify, define, explain, apply).
Phase 2 *Problem Orientation*	Identify the problem and formulate the problem
Phase 3 *Investigation*	Designing a investigation and collecting data
Phase 4 *Data Processing*	Interpreting and data analysis
Phase 5 *Explanation and Conclusion*	Explaining and conclusions of the investigation
Phase 6 *Communication*	Presenting the findings of the investigation and reflections

Social system

The social system describes the roles of teachers and students, the patterns of interaction employed, and the expected outcomes. The results of implementing the social system learning model within the I-BATARA model are shown in Table 3.

Table 3. Social system I-BATARA learning model

Syntax	Teacher's roles	Students' roles
Scaffolding based inquiry	Facilitator to guide students in connecting scientific concepts through the context batik Tanjung Bumi Madura	Students connect scientific concepts to the context of batik Tanjung Bumi Madura
Problem orientation	Guide students to identify and formulate problems based on issues raised by Tanjung Bumi batik	Identify the research question
Investigation	Facilitate students in designing an investigation within the context of Tanjung Bumi batik	Design a scientific investigation
Data processing	Guide students to analyse the data obtained	Analyse the data obtained from the investigation
Explain and conclude	Guide them to explain and draw conclusions	Explain the research findings and draw conclusions from the investigation
Communication	Guide students to communicate their findings regarding scientific concepts in Tanjung Bumi batik	Present the findings of the investigation into scientific phenomena in the batik-making process

Reaction principles

The principles of the I-BATARA model's responses involve how teachers observe and respond to students' actions, questions, mistakes, progress, or dynamics during the learning process. The specific principles of response for each phase are set out in Table 4.

Table 4. Reaction principles I-BATARA learning model

No	Syntax	Teacher's responses
1	Scaffolding based inquiry	Helping students construct an accurate scientific understanding of the phenomenon of batik
2	Problem orientation	Providing templates and concrete examples of problem formulation
3	Investigation	Not controlling the results, but fostering scientific habits
4	Data processing	Checking students' measurement results
5	Explain and conclude	Guiding students in organising their investigation findings
6	Communication	Observing students' presentations

Support system

The support system includes all interrelated components that enable the learning model to be implemented in the classroom. Support systems can be either physical or non-physical. Physical support systems in the I-BATARA model include student textbooks integrating batik Tanjung Bumi, student worksheets, videos on Tanjung Bumi batik, and the batik-making environment. Student textbook functions contextualize abstract scientific concepts within authentic batik-making practices to enhance cognitive relevance and scaffold students through the six-phase I-BATARA syntax. The student worksheet is used to guide students through the six-phase I-BATARA syntax with a structured procedural. Videos on batik Tanjung Bumi and the batik-making environment used provide contextualized visual documentation of Batik Tanjung Bumi processes to ground abstract scientific concepts in observable reality and scaffold understanding of abstract concepts. Non-physical support systems include students' psychological acceptance of lessons, a supportive learning environment, democratic learning, teachers' positive beliefs about students' learning experiences, and effective communication between teachers and students.

Instructional and accompanying impacts

Instructional impact, also known as direct impact, is the intended effect resulting from implementing the I-BATARA model. In this model, the instructional impact is measured by students' mastery of the core competency, namely, identifying elements, compounds, and mixtures in batik tulis Tanjung Bumi. In addition to achieving curriculum objectives, instructional impact encompasses specific student behaviors characteristic of the I-BATARA model, namely, science literacy. This instructional impact serves as a benchmark for field assessment of the quality of the products resulting from the development. A conducive learning environment is a key factor in learning. The learning environment in the development of the I-BATARA model refers to the overall conditions designed and managed to support the learning process in accordance with the characteristics of the model developed. The learning environment in the I-BATARA model encompasses physical, social, cultural, and pedagogical aspects.

Validity results of the I-BATARA and instructional package

The validity results of the I-BATARA model are presented in Table 5, which includes the validation scores and the assessment components for content and construct validity.

Table 5. Content and construct validity results of the I-BATARA learning model

Validation aspect	Assessment component	Validation score	Criteria	Percentage of Agreement (PoA %)	Reliability
Content Validity of I-BATARA Model	Current knowledge (state of the art)	4	Very valid	100	High reliability
	Theoretical and empirical support for I-BATARA	4	Very valid	100	High reliability
	I-BATARA model description	4	Very valid	100	High reliability
	Learning environment and classroom management	3	valid	85.71	High Reliability
Construct Validity of I-BATARA Model	Mode	4	Very valid	92.85	High reliability
	Review of the I-BATARA Model	4	Very valid	100	High reliability
	Planning and Implementation of the I-BATARA	4	Very valid	85.7	High reliability

Validation aspect	Assessment component	Validation score	Criteria	Percentage of Agreement (PoA %)	Reliability
	Model				
	Consistency in the management of the learning environment	4	Very valid	100	High reliability
	Evaluation I-BATARA model	4	Very valid	100	High reliability
	Mode	4	Very valid	92.85	High reliability

The validity results of the instructional package (such as the Lesson Plan (LP), Student Worksheet (SW), Student textbook (ST), and the scientific literacy test (SLT) showed average scores of 4, with the majority of agreement percentages exceeding 90%. These findings emphasize that the learning tools are highly valid, consistent, and reliable to support the implementation of the I-BATARA model. The validity of the instructional package is summarized in Table 6.

Table 6. Validity results of the I-BATARA model's supporting learning tools

Type of instructional package	Average validation score	Criteria	Percentage of agreement (PoA) %	Reliability
Validity of LP	4	Very Valid	95.23	High reliability
Validity of ST	4	Very Valid	92.80	High reliability
Validity of SW	4	Very Valid	95.23	High reliability
Validity of SLT	4	Very Valid	95.23	High reliability

Additionally, the validators provided feedback for improvement, particularly regarding the consistency of terminology, time allocation, and the presentation of the material, to further optimize the learning tools. Validator feedback highlighted inconsistencies in key terminology across instructional materials, particularly regarding inquiry-related terms and cultural epistemology concepts. In response, we developed a standardized glossary and conducted a cross-material terminological study. This refinement enhances conceptual clarity for both teachers and students, reducing cognitive load and supporting the implementation of the I-BATARA model. Validator feedback regarding the time allocation of the I-BATARA model.

Additionally, we developed flexible implementation pathways and embedded time-management scaffolds in the teacher guide. The validation results of the I-BATARA model and its supporting learning tools indicate that all components fall within the "very valid" category, with reliability levels ranging from high to excellent. These results indicate that the components of the I-BATARA model—comprising syntax, reaction principles, the social system, the support system, instructional impact, and accompanying impact—are logically consistent with its philosophical foundation. The I-BATARA model is ready to be piloted in the classroom.

Discussion

Alignment of development results with theoretical foundations

The I-BATARA model was developed in response to the limitations of the Inquiry model, in which both students and teachers still struggled to formulate questions, and the process of support provided to students was not yet apparent. Scaffolding-based inquiry is the key innovation that distinguishes this model from others. This scaffolding helps students ask questions, which is the core of inquiry. Theoretically, the I-BATARA model is supported by Piaget's constructivist theory, which states that constructivism encompasses two basic ideas: that students actively construct their own knowledge, and that social interaction is crucial in the process of knowledge formation. In summary, there are two forms of constructivism: psychological and social. Piaget's constructivism explains the cognitive processes by which students construct their knowledge. In this theory, knowledge is formed from prior knowledge through the transformation, organization, and reorganization of that knowledge.

The knowledge acquired is not a reflection of the external world; rather, the thought processes and experiences gained influence the knowledge that is formed. In this process, exploration is crucial to the formation of knowledge (Moshman, 1982). Vygotsky's social constructivist theory emphasises social interaction with society, local culture, and individual development and learning activities (Woolfolk, 2012), whilst David Ausubel's theory of meaningful learning posits that the learning process guides students to construct knowledge by integrating new information and experiences into existing knowledge structures Meaningful learning occurs when learners are actively engaged in understanding new information, making connections with prior knowledge, and applying it in new contexts. The aim of meaningful learning is for students to gain a deep understanding, rather than merely memorizing facts and procedures (Abu-Rasheed et al., 2023). The next theory is situated learning theory, which states that learning emphasizes authentic contexts already familiar to students, and that the learning process involves not merely the acquisition of knowledge and skills but also knowledge of the social and cultural aspects of the local community (Lave & Wenger, 1991).

Validity of the i-batara model and instructional package

The validation results for the I-BATARA model show that both content validity and construct validity fall within the "very valid" category, with a modus score of 4 and an agreement percentage among validators exceeding 92%, indicating that the expert evaluations of the model are consistent and reliable. This result suggests that the model has been designed with strong conceptual and empirical foundations, in line with the model development principles outlined and the importance of rationales, syntax, social systems, reaction principles, and instructional impacts in a learning model (Joyce et al., 2014).

In terms of content validity, all five components evaluated rationale for model development, state-of-the-art knowledge, theoretical and empirical support, model description, and classroom management were deemed "very valid." The average content validity score of the I-BATARA model was 0.92, indicating very good validity, and the reliability was 92.85%. The analysis of the I-BATARA learning model was considered highly relevant to the demands of 21st-century education in the aspects of global awareness, citizenship literacy, and collaboration skills. Students can learn individually, in partnerships, or in groups, studying various indigenous knowledge from their surroundings, religion, and lifestyle with a spirit of mutual respect in personal, work, and community contexts (Sefoka & Chuene, 2025). I-BATARA provides a validated framework that systematically integrates batik Tanjung Bumi into scientific literacy instruction. Model I-BATARA confirms that the inquiry-based syntax logically scaffolds knowledge construction and aligns with constructivist and culturally responsive pedagogy. By prioritizing local contexts, these practices ensure that learning is relevant, meaningful, and sustainable, addressing the unique needs and aspirations of students (Jaiswal, 2025).

Regarding construct validity, the results demonstrate the model's internal coherence and consistency across its components. The average construct validity score also reached 4, with a PoA of 92.85%. This indicates that the review of the I-BATARA Model, the planning and implementation of the I-BATARA Model, the consistency in the management of the learning environment, and the evaluation of the I-BATARA Model have been logically and functionally integrated throughout the model's design. These findings are further supported by Table 5, which outlines the strengths of each validation element. Consequently, these validation results affirm that the I-BATARA model, in both structure and content, is well-prepared for implementation in science education to enhance scientific literacy. Integrating construct validation into open science reform can improve transparency in measurement development and use, enhancing the validity of replication studies in educational learning.

In addition to the I-BATARA model, supporting learning tools such as learning planning and student worksheets also received excellent validity results, with scores exceeding 4 and reliability values ranging from 100% to 85.71%, as shown in Table 6. These tools not only facilitate the smooth implementation of the model but also strengthen the measurability of the expected learning outcomes, namely, the high validity of the student worksheet and the scientific literacy test. The student textbook meets the criteria for high validity, which is particularly significant as it is directly linked to student learning activities and the assessment of scientific literacy. These findings align with the research (Aditomo & Klieme, 2020; Puspitarini et al., 2025; Widarti et al., 2025). Lesson plan is very valid when expert judgment confirms that its components learning objectives, instructional activities, assessment strategies, time allocation, and resource specifications are theoretically aligned with the underlying pedagogical framework; empirically grounded in evidence-based practices for the target learning outcomes scientific literacy; contextually appropriate for the intended learners and setting in batik Tanjung Bumi; and operationally feasible for implementation by teachers with available resources. A quality lesson plan should have clear learning objectives, measurable content, effective time management, and align with the curriculum and learning goals (Ruhozu & Mwanza, 2025). The student textbook meets the criteria for high validity, meaning that the language, communication, pedagogical approach, cultural sensitivity, assessment, exercises, and visual aids are clear to the student (Zeynivandnezhad et al., 2024). This study successfully developed the I-BATARA learning model, which is valid and ready for widespread implementation.

Beyond its methodological contribution, the validation of the I-BATARA model underscores its potential to advance SDG 4 (Quality Education). By providing a culturally relevant and scientifically grounded instructional framework, the model supports efforts to strengthen students' scientific literacy through meaningful and context-based learning experiences. Although broader sustainability outcomes require further empirical investigation, the validated design offers a promising foundation for promoting quality science education that is responsive to local cultural contexts.

CONCLUSION

Fundamental Finding: The validity of the model and its supporting instructional package, including the Lesson Plan, Student Worksheet, Learning Materials, and Scientific Literacy Test, demonstrates very high levels of validity and reliability, indicating the model's readiness for widespread implementation. **Implication:** The I-BATARA model is designed to enhance science literacy by integrating local knowledge of Tanjung Bumi batik with contexts relevant to the pupils; it is hoped that pupils will be able to receive, interpret data, communicate, and reflect on the information they receive. This process begins with a scaffolding-based inquiry approach comprising the stages of identification, definition, explanation, and application. The application of this model is also in line with cognitive constructivism, social constructivism, meaningful learning, and situated learning theory. These implications further support SDG 4 (Quality Education) by promoting culturally relevant and context-based science learning experiences that strengthen students' scientific literacy and foster meaningful participation in evidence-based decision-making. **Limitation:** This learning process focuses on a single type of local heritage, namely Batik Tanjung Bumi. **Future Research:** The I-BATARA model should be evaluated to assess its effectiveness in improving science literacy in junior high schools, senior high schools, and colleges. It is recommended that higher education institutions and science educators implement the I-BATARA learning model.

AUTHOR CONTRIBUTIONS

Wiwin Puspita Hadi contributed to the conceptualization of the study, research design, data collection, investigation, data analysis, interpretation of findings, and preparation of the original manuscript draft. **Erman** contributed to methodology development, validation of research findings, supervision of the research process, critical review of the manuscript, and refinement of the theoretical framework. **Suyatno Sutoyo** contributed to research supervision, project administration, validation, interpretation of results, and manuscript review and editing. All authors have read, reviewed, and approved the final version of the manuscript for submission and publication.

CONFLICT OF INTEREST STATEMENT

The authors confirm that there are no conflicts of interest, either financial or personal, that may have influenced the content or outcome of this study.

ETHICAL COMPLIANCE STATEMENT

This manuscript complies with research and publication ethics. The authors affirm that the work is original, conducted with academic integrity, and free from any unethical practices, including plagiarism.

STATEMENT ON THE USE OF AI OR DIGITAL TOOLS IN WRITING

The authors acknowledge the use of ChatGPT (OpenAI) as an AI-assisted writing tool during the preparation of this manuscript. ChatGPT was used to support language editing, grammar refinement, academic paraphrasing, and improvement of manuscript clarity and readability. All AI-generated outputs were carefully reviewed, verified, and revised by the authors to ensure accuracy, originality, academic integrity, and compliance with ethical research standards. The authors take full responsibility for the content of this manuscript and all conclusions presented therein.

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