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The I-BATARA Learning Model: A Conceptual Framework Integrating Inquiry, Scaffolding, and Local Wisdom to Foster Scientific Literacy

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ABSTRACT

Objective: *Scientific literacy, a foundational literacy, is essential for students to develop from an early age to prepare them for addressing the challenges of the global era. Therefore, effective instructional interventions are required to facilitate students' transition from concrete to abstract thinking by employing meaningful real-world contexts. This research tries to formulate the I-BATARA learning model to increase the student's scientific literacy.* ***Method:*** *This study employed a conceptual model development approach to construct the I-BATARA learning model.* ***Results:*** *The results indicate that the proposed I-BATARA instructional model integrates Inquiry-Based Learning, process-oriented scaffolding, and the authentic context of batik tulis Tanjung Bumi Madura into a coherent instructional framework designed to enhance students' scientific literacy.* ***Novelty:*** *The I-BATARA learning model its comprehensive integration of Inquiry-Based Learning (IBL), scaffolding, local wisdom, and scientific literacy instructional framework.*

INTRODUCTION

Scientific literacy is one of the most important skills and should be strengthened by the students. Students with scientific literacy skills will be able to apply the knowledge learned to solve problems in good everyday life (Jufrida et al., 2019). Scientific literacy, a foundational literacy, is essential for students to develop from an early age to prepare them for addressing the challenges of the global era. (González & Reiss, 2023; Wakhidah et al., 2022). Students with science literacy are expected to be able to make decisions regarding environmental issues affecting the community (Christensen, 2023; Mart & Gonz, 2022), to be able to make decisions with confidence in various situations (Al Sultan et al., 2021) and to improve their understanding of science in order to solve global social challenges and promote sustainability (Georgiou & Kyza, 2023).

However, research in Indonesia indicate that student's scientific literacy still low. A research study at a university found that students only reached the nominal level at 66.2 % and the functional level at 33.8 % indicating an ability to understand concepts and relate them to one another, but they still have a tendency to hold misconceptions (Melinda et al., 2021). Students understand the concepts but are unable to relate them to everyday life and are not used to applying them in context (Fitriani et al., 2018; Purwani et al., 2018) . Scientific literacy among students at an Islamic boarding school in a city in East Java was in the low category, with an average score of 32.70 (Rosidi, 2021). Furthermore, the results of the 2022 PISA assessment indicate that, in terms of science literacy, Indonesia ranked 67th out of 81 participating countries with a score of 383 (OECD, 2023). These findings suggest that students' science literacy is still low, which results in difficulties in applying scientific knowledge to solve problems and make decisions in everyday life.

The low level of scientific literacy is attributed to several factors, including students' inability to integrate procedural knowledge when identifying appropriate scientific explanations (Innatesari et al., 2019). Consequently, they have difficulty interpreting the data and drawing valid conclusions based on the evidence (Sholahuddin et al., 2021), learning activities in the classroom have not been contextualized, teachers' limited ability to integrate authentic real-world contexts with the underlying scientific concepts (Dunlop & Veneu, 2019; El Arbid & Tairab, 2020). Moreover, students demonstrate predominantly concrete thinking, need for instructional interventions that scaffold the transition from concrete experiences to abstract conceptual understanding (Erman & Wakhidah, 2023).

Therefore, effective instructional interventions are required to facilitate students' transition from concrete to abstract thinking by meaningful learning contexts. Meaningful learning context facilitate students' understanding of science concepts. In exploring the scientific world, inquiry-based learning the instructional approaches commonly implemented in science education to promote students' active engagement in scientific inquiry (Kousloglou et al., 2023). However, the implementation of inquiry-based learning faces several challenges, including its limited effectiveness for students with lower cognitive abilities and those with limited practical skills (Fatmawati & Rustaman, 2020) and challenges in formulating hypotheses, collecting and interpreting evidence, constructing scientific explanations and evidence-based conclusions (Chokchai & Pimdee, 2019; Yao et al., 2016). Science teacher still need guidance and development to teach using the inquiry model (Weldmeskel, 2026). Inquiry-based learning approaches focus on continuous guidance, meaning that students tend not to be independent, while open inquiry can lead to cognitive overload for less experienced student’s (Ariza et al., 2020; Nicol, 2021). Furthermore, challenges remain in implementing inquiry-based learning, highlighting the need for more interactive instructional strategies and learning contexts that are meaningful to students (Büyükbayrakta, 2023).

Therefore, integrating scaffolding into inquiry-based learning is considered an effective approach to addressing scientific literacy. Scaffolding enables students to address learning challenges and task demands by providing timely support, guidance, and structured assistance that is adjusted to their current level of understanding (Fitriyah et al., 2020; Kusmaryono & Wijayanti, 2020). The scaffolding in science education help students to develop conceptual understanding and improve their retention of instructional content (Chang & Yang, 2023; Masava et al., 2023), improve students’ achievement (Hayati et al., 2024), science process skills (Senisum et al., 2022), and scientific literacy (I. N. Sari et al., 2024; Tegeh et al., 2021). However, the implementation of scaffolding often encounters several challenges, including excessive instructional support and the failure to adapt scaffolding to students' individual learning needs. As a result, students may become overly dependent on teacher assistance, limiting the development of their scientific skills (Tatum & Huber, 2020). Therefore, a systematic and progressively scaffolding approach is required throughout the learning process.

Inquiry-based learning and scaffolding are expected to improve students' scientific literacy through the use of local wisdom as a familiar and culturally relevant learning context (Ogundeji et al., 2019). The learning context should be familiar to students to minimize cognitive overload during the learning process. Based on previous research, there are three factors that influence science learning integrated with local wisdom, namely indigenous worldview, community participation, and linguistic ecology (Silva et al., 2024). Several challenges remain in integrating local wisdom into science learning, including limited teacher competence in designing instructional materials and connecting local culture with academic content (Hikmawati et al., 2021), the dominance of western knowledge systems in science learning(Sadri et al., 2025) , and the highly context-specific nature of local settings, which may limit the generalizability of research findings (Hlalele, 2019).

Local wisdom as an authentic, meaningful, and culturally relevant learning context. Although Madura possesses abundant forms of local wisdom, not all of them provide comprehensive opportunities for integrating scientific concepts into science learning. Therefore, selecting an appropriate local wisdom context must consider its educational relevance, scientific concept, cultural potential to support inquiry-based learning (Cai et al., 2022; Marsico & Dazzani, 2022). Batik Tulis Tanjung Bumi was selected because its traditional production process naturally integrates multiple scientific concepts namely natural or synthetic dye, heat transfer, physical and chemical changes, properties of materials, and environmentally sustainable production practices (Afrida et al., 2025; Hadi et al., 2025; Martareza et al., 2025). Furthermore, batik tulis Tanjung Bumi reflects the cultural identity of the Madurese community through traditional motifs and, indigenous. These characteristics provide authentic learning experiences that enable students to connect scientific concepts with their cultural heritage and cultural preservation (Zidny & Eilks, 2022).

Based on the foregoing discussion and to address the limitations associated with the implementation of inquiry-based learning, scaffolding, and local wisdom, this study proposes their integration into a holistic and systematically designed instructional framework. Within this framework, inquiry serves as the overarching pedagogical approach that guides students in constructing knowledge through scientific inquiry processes. Scaffolding functions as an adaptive instructional support strategy that assists students throughout the inquiry process, whereas local wisdom provides an authentic and culturally relevant learning context rather than serving as a teaching method or instructional strategy.

Therefore, the I-BATARA learning model extends existing inquiry-based learning approaches by introducing a theoretically integrated framework that systematically combines inquiry, process-oriented scaffolding, and local wisdom contexts. The novelty of this model structured role assigned to each component in the instructional process. Inquiry functions as the central pedagogical framework for engaging students in scientific investigation, local wisdom provides an authentic and culturally meaningful context for constructing scientific knowledge, and scaffolding is systematically embedded across each inquiry phase to provide adaptive support according to students' cognitive needs. Furthermore, I-BATARA positions scientific literacy as the ultimate learning objective by enabling students to explain phenomena, interpret evidence, and apply scientific knowledge in authentic contexts.

The research problem is formulated how is the development of a hypothetical I-BATARA learning model (Inquiry Learning Model Based on Local Wisdom Batik Tulis Tanjung Bumi Madura) to foster student’s scientific literacy?

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RESEARCH METHOD

This study employed a conceptual model development approach to construct the I-BATARA learning model. The conceptual framework was developed involved four stages. First, the theoretical foundations of inquiry-based learning, scaffolding, local wisdom, and scientific literacy were identified through a narrative review of the relevant literature. Second, the characteristics, strengths, and limitations of these approaches were critically compared to identify their complementary roles. Third, the findings were conceptually synthesized into a coherent instructional framework. Finally, the instructional syntax, purposes, theoretical foundations, social system, reaction principles, support system, instructional impacts, and accompanying impacts of the I-BATARA learning model was developed based on the results of this conceptual synthesis.

RESULTS AND DISCUSSION

Results

The findings of this study indicate the need to develop an instructional model. The detailed results of each analysis are presented as follows.

Literature Analysis

Inquiry Based Learning

Inquiry-Based Learning (IBL) has been widely implemented to enhance students' scientific literacy (Heppt et al., 2022; Sotiriou et al., 2020). The effectiveness of scientific literacy development is influenced by the quality of inquiry-based instruction and the specific type of inquiry model implemented. In addition, other contributing factors include classroom management, teachers' adaptability, teacher– student relationships, and instructional support provided by teachers (Kang, 2022).

Teacher guidance remains essential in Inquiry-Based Learning, particularly in supporting students to represent problems, generate solutions, justify their reasoning using evidence, and monitor and evaluate their problem-solving processes, as students often experience difficulties in evaluating the solutions they produce (Orosz et al., 2023). Furthermore, inquiry-based learning provides opportunities for students to develop a range of scientific reasoning skills, including the ability to make informed decisions when addressing complex problems (Wilder, 2015)

However, several limitations of Inquiry-Based Learning is implemented within the batik tulis Tanjung Bumi, Students tend to engage in practical activities primarily to verify established scientific concepts rather than to construct new conceptual understanding through inquiry. Moreover, these learning experiences are often not supported by sufficient critical thinking or by a learning environment that effectively facilitates knowledge construction (Oliver et al., 2021). Students generally show greater interest in hands-on practical activities; however, this enthusiasm is not always accompanied by adequate experimental competence (Hodson, 2014).

Local Wisdom and Context- based Learning

One of the major challenges in science education is students' perception that science is neither interesting nor relevant, resulting in low interest in learning science (Steidtmann et al., 2022). One of the primary reasons why science is perceived as irrelevant is the limited connection between scientific concepts and students' everyday experiences (Childs & Hayes, 2015). Science education is expected to prepare students to become critical, creative, and responsible citizens who are capable of responding to societal issues arising and advances in science and technology (Lindholm, 2018). Therefore, science learning should acquisition of scientific theories and facts by integrating life experiences and social contexts as the foundation for learning, making science more meaningful and relevant to students (Gong & Janssen, 2019).

Local wisdom embedded communities can serve as a meaningful learning context for connecting scientific concepts with students' everyday lives. Local wisdom is generally defined as locally developed knowledge, values, and practices that embody wisdom, are socially recognized as beneficial, and are deeply embedded in the traditions and daily lives of community members (Sumarni, 2018). It may originate from the indigenous knowledge of a particular community or evolve through the adoption and adaptation of external cultural practices. Regional characteristics, including environmental conditions and local resources, often influence this adaptation process, leading to the development of unique forms of local wisdom that distinguish one region from another. Consequently, although certain cultural practices may have originated elsewhere, they are frequently modified to according local environmental and socio-cultural contexts and eventually become recognized as distinctive local wisdom of the adopting community.

Various instructional approaches have been developed to enhance students' scientific literacy by incorporating meaningful learning contexts. Batik tulis Tanjung Bumi Madura is considerable potential and close relevance to students' daily lives in Bangkalan. This cultural heritage possesses distinctive characteristics that have evolved over successive generations and reflect the unique environmental, cultural, and socio-economic conditions of the region, making it different from batik traditions found in other areas (I. P. Sari, 2022). Furthermore, continuous efforts have been undertaken by the local community to preserve and sustain this cultural heritage. Batik tulis Tanjung Bumi Madura is particularly suitable for science learning because its production processes contain of scientific concepts. Integrating this local wisdom into science instruction is therefore expected to improve both students' learning outcomes and their scientific literacy (Hadi et al., 2025). Moreover, meaningful learning experiences derived from authentic cultural contexts facilitate students' understanding of scientific concepts while fostering curiosity, critical thinking, and responsible attitudes toward learning and society (Marsico & Dazzani, 2022).

Analysis for Scaffolding

Students experienced difficulty in identifying scientific problems from contextual phenomena (Maia et al., 2021). Most students tended to wait for the teacher's guidance rather than independently generating investigable questions. The problems formulated were generally descriptive and lacked a clear scientific focus. The scaffolding provided during the learning process comprises three components: (1) scaffolding designed to activate students' prior knowledge of the target concepts; (2) scaffolding aimed at connecting science content to the contextual setting employed in instruction; and (3) scaffolding intended to establish links between the learning context and socio-scientific issues (SSI) (Erman et al., 2022).

Students demonstrated limited ability to formulate hypotheses based on prior scientific knowledge. Most hypotheses were expressed as simple predictions without providing scientific reasoning or justification. This finding indicates that students had difficulty connecting existing concepts with the observed phenomena. Students encountered challenges in planning investigation procedures independently (Kranz et al., 2022). The analysis also showed that students had difficulty organizing, interpreting, and explaining experimental results using scientific concepts. Students tended to describe observational data without analyzing relationships among variables or drawing evidence-based explanations.

At the final stage of inquiry, many students were unable to formulate conclusions that were fully supported by empirical evidence. Conclusions were often based on personal opinions or incomplete observations rather than logical interpretation of the collected data. Scaffolding can be classified into four types: conceptual, procedural, metacognitive, and strategic scaffolding (Hannafin et al., 1999). Conceptual scaffolding was identified as necessary during the orientation and problem-identification stages. Students require guidance to activate prior knowledge, understand relevant scientific concepts, recognize scientific phenomena within the context of batik tulis Tanjung Bumi, and formulate investigable scientific questions. Metacognitive scaffolding was identified as necessary during the reflection and evaluation stages (Kim & Hannafin, 2011). Students require prompts that encourage them to monitor their own thinking, evaluate the validity of evidence, reflect on investigation procedures, and formulate conclusions based on scientific evidence.

The overall analysis indicates that students require continuous instructional support throughout the inquiry process rather than only at the beginning of learning. Therefore, the I-BATARA learning model incorporates three complementary forms of scaffolding—conceptual, procedural, and metacognitive scaffolding—that are systematically embedded within each phase of inquiry to facilitate students' progression from guided inquiry toward greater learning independence. Scaffolding embedded within the local wisdom context of Batik Tulis Tanjung Bumi enables students to enhance their ability to formulate questions, which serves as a fundamental component of the inquiry process.

The needs analysis revealed seven key findings: (1) the curriculum emphasizes scientific literacy and inquiry-based learning but provides limited guidance on integrating local wisdom; (2) previous studies consistently support the roles of inquiry, scaffolding, and contextual learning, yet their integration remains limited; (3) science instruction is still predominantly teacher-centered; (4) students require stronger support in developing scientific literacy competencies; (5) existing learning models have not comprehensively integrated inquiry, scaffolding, and local wisdom; (6) Tanjung Bumi Batik offers rich scientific contexts that are relevant to science learning; and (7) systematic scaffolding is needed to support students throughout the inquiry process. These findings provided the empirical and theoretical foundation for developing the I-BATARA learning model.

Results of Theoritical Syntesis

The development of the I-BATARA instructional model is grounded in four complementary learning theories: Piaget's constructivist theory, Vygotsky's sociocultural theory, Ausubel's meaningful learning theory, and Situated Learning Theory. Constructivist theory is based on two fundamental assumptions: (1) learners actively construct their own knowledge, and (2) social interaction plays an essential role in knowledge construction. Constructivism encompasses two complementary perspectives: psychological constructivism and social constructivism. Piaget's constructivist theory emphasizes the cognitive processes through which learners construct knowledge. According to this theory, new knowledge is built upon prior knowledge through continuous processes of transformation, organization, and reorganization. Knowledge is therefore not a direct representation of the external world but rather the result of learners' cognitive processes and experiences. Consequently, exploration plays a central role in facilitating conceptual development. Within the I-BATARA model, exploration is designed to enable students to investigate authentic problems related to batik tulis Tanjung Bumi and to propose possible solutions. Students are expected to apply their prior scientific knowledge while integrating the social and cultural dimensions of Tanjung Bumi batik (societal concerns) into the inquiry process. Through this approach, students construct scientific knowledge by connecting scientific concepts with authentic local contexts.

Vygotsky's sociocultural theory argues that intellectual development occurs when learners encounter new experiences and attempt to resolve discrepancies between their prior understanding and new information. Knowledge is constructed through collaboration, participation in social groups, and interaction within cultural contexts. One of the central concepts of Vygotsky's theory is the Zone of Proximal Development (ZPD), which refers to the range of tasks that learners can accomplish with guidance from teachers or more knowledgeable individuals. Within the ZPD, learning is facilitated through scaffolding, enabling students to perform tasks that would otherwise exceed their independent capabilities. Cultural tools and artifacts also play a crucial role in mediating learning and cognitive development (Woolfolk, 2012).

Ausubel's meaningful learning theory emphasizes that meaningful learning occurs when new information is consciously related to learners' existing cognitive structures (Bryce & Blown, 2024). During the learning process, students assimilate new concepts by integrating them with previously acquired knowledge. Therefore, teachers should first identify students' prior understanding, such as their existing knowledge of batik tulis Tanjung Bumi, before introducing new scientific concepts. For example, students' prior experiences with batik production can be linked to scientific concepts such as physical and chemical changes occurring during the dyeing process. This integration enables students to develop meaningful conceptual understanding rather than merely memorizing isolated fact.

Situated learning theory, developed by Lave and Wenger (1991), emphasizes that learning should occur within authentic contexts that are familiar and meaningful to learners. Learning is viewed not merely as the acquisition of knowledge and skills but as active participation in the social and cultural practices of a community (Lave & Wenger, 1991). According to this perspective, meaningful learning emerges through active participation, collaboration, and interaction within authentic learning environments. The I-BATARA model situates science learning within the authentic context of Tanjung Bumi traditional batik, enabling students to develop both scientific knowledge and practical skills while engaging with local cultural practices (Abu-Rasheed et al., 2023). This approach aligns with student-centered learning and constructivist principles by integrating authentic contexts with collaborative social interaction).

Furthermore, situated learning encourages students to make informed decisions while addressing authentic problems encountered in the Tanjung Bumi batik context. Learning activities incorporate social participation and community engagement to facilitate meaningful knowledge construction (Lave & Wenger, 1991). This perspective complements cognitive constructivism by emphasizing the sociocultural dimensions of learning, where knowledge is continuously transformed through participation in social practices (Affognon, 2026). Consequently, situated learning is often described as a process of enculturation, through which learners acquire the norms, values, behaviors, language, skills, and practices of a particular community (Renkl, 2001).

Results of Conceptual Framework Development

The I-BATARA instructional model was developed based on the principles of Inquiry-Based Learning (IBL), with the primary objective of fostering students' curiosity about local wisdom while enhancing their scientific thinking skills. In this model, students engage in scientific investigations of problems derived from the context of local wisdom, supported by systematic scaffolding. The learning process is designed to enable students to construct scientific knowledge through inquiry, develop scientific reasoning skills, and cultivate scientific attitudes, particularly toward the application of the scientific method.

Students' ability to formulate meaningful, concept-based questions is facilitated through scaffolding provided at the beginning of the learning process. Such support activates students' prior knowledge, which serves as the cognitive foundation for learning. This prior knowledge, acquired through informal experiences, observations of the surrounding environment, and previous learning experiences, provides the basis for transforming and reconstructing existing knowledge into new conceptual understanding

Developing students' understanding of scientific concepts requires engagement in authentic scientific practices. Accordingly, teachers provide scaffolding through activities that encourage students to identify, define, and explain scientific phenomena associated with Tanjung Bumi traditional batik. These scaffolded inquiry activities support students in constructing scientific concepts by connecting prior knowledge with authentic local contexts.

The comprehensive conceptual framework underpinning the development of the I-BATARA instructional model is presented in Figure 1.

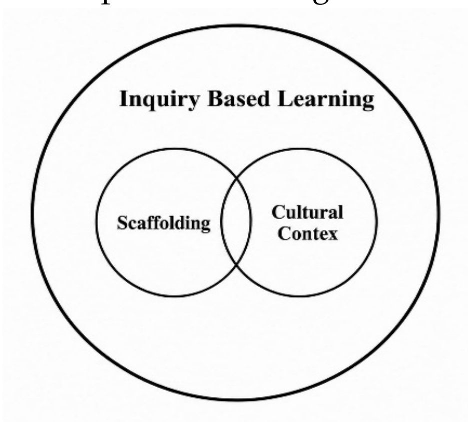

Figure 1. The I-BATARA learning model framework

Component I-BATARA Learning Model

Syntax

The syntax of the I-BATARA learning model constitutes the core instructional component that operationalizes the conceptual framework into a sequence of coherent learning activities. It was developed by integrating the essential principles of inquiry-based learning with scientific literacy competencies, scaffolding strategies, and the authentic context of Tanjung Bumi batik local wisdom. Consequently, each instructional phase is designed not only to facilitate students' inquiry processes but also to provide structured learning support that gradually shifts responsibility from the teacher to the students. Details of the I-BATARA model syntax, activity descriptions, supporting learning theories, and the scientific literacy indicators fostered are shown in Table 1.

Table 1. Details of the syntax, activity descriptions, and indicators of scientific literacy

I-BATARA Syntax	Activity Description	Indicators of Scientific Literacy Fostered
Scaffolding based inquiry	Students connect scientific concepts to the context of local wisdom through scaffolding based on the IDEA strategy (Identify, Define, Explain, and Apply)	Explain phenomena scientifically
Problem Orientation	Student identify anda formulate problem	Explain phenomena scientifically
Investigation	Design and conduct investigations to collect evidence needed to address the proposed research questions.	Explain phenomena scientifically
Data Processing	Interpret and analyze the collected data to draw evidence-based conclusions from the investigation	Evaluate and design scientific enquiry
Explanation and conclusion	Explain and formulate scientific concepts based on the analysis and interpretation of the investigation results	Evaluate and design scientific enquiry
Communication	Present and communicate the findings	Interpret data and evidence scientifically

Social System

The teacher demonstrates a thorough understanding of the instructional procedures by orienting students through authentic information or phenomena that stimulate questioning and initiate the inquiry process. Effective implementation of inquiry learning promotes the development of students' scientific thinking and higher-order thinking skills (Sotiriou et al., 2020; H. H. Wang et al., 2022) . Students actively explore information related to batik tulis Tanjung Bumi Madura to construct scientific concepts, understand its social and cultural dimensions, and transform knowledge across scientific and socio-cultural perspectives.

Principles of Reaction

The principles of reaction describe how the teacher interacts with students, including how the teacher attends to and supports learners, as well as responds to their questions, answers, ideas, and actions during both individual and collaborative learning activities

Support System

The support system for the Model of Learning Inquiry based on Local Wisdom Batik Tulis Tanjung Bumi Madura (I-BATARA) includes the following: Instructional materials developed for the I-BATARA model, including teaching modules, student worksheets (worksheets for inquiry activities), local wisdom-based instructional materials on batik tulis Tanjung Bumi Madura, and scientific literacy assessment instruments. Supporting learning resources, including textbooks, e-books, articles, and other relevant references related to the learning topics and scientific concepts. Instructional media, including batik Tanjung Bumi video and other multimedia resources that support the learning content and inquiry activities.

Instructional Effects

Instructional effects refer to the intended learning outcomes that are directly achieved through the implementation of the instructional model (Klepsch & Seufert, 2020). An instructional model is considered effective when it successfully facilitates the attainment of its predetermined instructional objectives. The primary instructional effect of the I-BATARA is the enhancement of students' scientific literacy.

Nurturant Effects

Nurturant effects refer to the indirect learning outcomes that emerge during the instructional process, encompassing both cognitive and affective development. Through the implementation of the I-BATARA model, the expected nurturant effects include fostering students' motivation to learn about and preserve Tanjung Bumi Madura traditional batik as an important form of local cultural heritage, enhancing students' communication skills, and strengthening their commitment to environmental sustainability by promoting awareness of environmental pollution caused by batik dyeing waste.

Novelty of the I-BATARA Learning Model

The novelty of the I-BATARA instructional model lies in its comprehensive integration of Inquiry-Based Learning (IBL), process-oriented scaffolding, local wisdom, and scientific literacy within a single coherent instructional framework. I-BATARA learning model systematically incorporates scaffolding throughout each stage of the inquiry process to provide adaptive support that enables students to formulate meaningful questions, design investigations, analyze evidence, construct scientific explanations, and communicate their findings. This process-oriented scaffolding facilitates the gradual development of students' conceptual understanding and scientific reasoning while promoting independent learning

Furthermore, scientific literacy serves as the central instructional goal that guides the design of the model's syntax, learning activities, and assessment. Consequently, the I-BATARA model is not simply a modification of existing inquiry-based learning models; instead, it represents a novel conceptual framework that coherently integrates contemporary learning theories, local cultural contexts, process-oriented scaffolding, and scientific literacy into a unified instructional design.

Discussion

The development of the I-BATARA learning model to improve students' scientific literacy. Scientific literacy extends beyond the acquisition of scientific knowledge to encompass the ability to explain scientific phenomena, evaluate and design scientific enquiries, and interpret data and evidence to make informed decisions (OECD, 2023). However, many students continue to experience difficulties in developing these competencies because science instruction often emphasizes content acquisition rather than engagement in authentic scientific inquiry (Hughes et al., 2023; Nasr, 2021).

Inquiry-Based Learning (IBL) has been widely recognized as an effective instructional approach for promoting scientific literacy (Onorato et al., 2026; Simatupang et al., 2026). Nevertheless, its effectiveness largely depends on the quality of implementation and the instructional support provided to students. Accordingly, the I-BATARA model positions scientific literacy as the overarching instructional goal and integrates it systematically into every phase of the learning process. However, Inquiry-Based Learning its implementation frequently presents challenges. Students often find difficult to formulate research questions, develop hypotheses, design investigations, analyze data, and construct evidence-based conclusions (Kranz et al., 2023) . Previous studies have shown that, without appropriate instructional support, inquiry-based learning may impose a high cognitive load, resulting in sub optimal learning outcomes, particularly among students with limited experience in scientific investigation. Therefore, the I-BATARA model does not merely adopt inquiry as its instructional approach but complements it with systematically designed process-oriented scaffolding that provides adaptive support throughout the inquiry process.

The theoretical foundation of the I-BATARA model integrates four complementary learning theories, contributing how students construct scientific understanding. Piaget's constructivist theory explains that knowledge is actively constructed through learners' interactions with their environment . Learning occurs through the cognitive processes of assimilation, accommodation, and equilibration, enabling students to continuously reorganize and refine their conceptual understanding (Kusmaryono et al., 2022). From this perspective, science learning should actively engage students in observing, investigating, and constructing scientific concepts through direct experience rather than relying solely on teacher-centered instruction.

While Piaget emphasizes individual cognitive construction, Vygotsky's sociocultural theory highlights the importance of social interaction in facilitating learning (Ofori-attah, 2021). Central to this theory are the concepts of the Zone of Proximal Development (ZPD) and scaffolding, which suggest that students can achieve higher levels of understanding when provided with appropriate guidance from teachers or prior knowledge. Consequently, scaffolding is integrated throughout the I-BATARA model to support students in formulating problems, designing investigations, interpreting evidence, and constructing scientific explanations while gradually fostering independent learning.

In addition, Ausubel's Meaningful Learning Theory emphasizes that meaningful learning occurs when new information is connected to learners' existing cognitive structures. Prior knowledge serves as the foundation upon which new concepts are assimilated and integrated (Wing et al., 2022). Therefore, the I-BATARA model activates students' prior knowledge of Tanjung Bumi traditional batik before introducing new scientific concepts, enabling students to relate unfamiliar scientific ideas to their previous experiences and thereby facilitating meaningful conceptual understanding.

Finally, situated learning theory argues that knowledge is more effectively acquired when learning occurs within authentic social and cultural contexts . Learning is not only learn of abstract concepts but also the application of those concepts in meaningful real-world situations (M. Wang et al., 2025) . Accordingly, the I-BATARA model situates science learning within the authentic context of Tanjung Bumi Madura traditional batik, allowing students to investigate scientific phenomena embedded in local cultural practices. This authentic context not only enhances conceptual understanding but also promotes the development of scientific literacy by enabling students to apply scientific knowledge to socially and culturally relevant issues (Rubini et al., 2019).

Collectively, these four theoretical perspectives provide a coherent foundation for the development of the I-BATARA instructional model. Piaget's theory explains how students construct knowledge through cognitive processes; Vygotsky's theory provides the pedagogical basis for scaffolding and collaborative learning; Ausubel's theory emphasizes the importance of activating prior knowledge to facilitate meaningful learning; and Situated Learning Theory situates scientific inquiry within authentic local contexts. The integration of these theories enables the I-BATARA model to support students in constructing scientific knowledge, engaging in inquiry, and developing scientific literacy through meaningful interactions with the local wisdom of batik tulis Tanjung Bumi.

In sum, these theoretical perspectives suggest that the I-BATARA learning model makes a significant theoretical contribution to science education by integrating the strengths of inquiry-based learning, context-based learning, ethnoscience-based learning, and scaffolding into a coherent instructional framework. The I-BATARA learning model aims to foster students' curiosity about local wisdom and develop their scientific thinking skills. Through teacher-provided scaffolding, students are guided to conduct scientific investigations based on problems derived from local wisdom contexts, enabling them to construct scientific knowledge through evidence-based inquiry. Inquiry-based learning emphasizes students' active engagement in the scientific inquiry process to construct knowledge and draw evidence-based conclusions (Johnston et al., 2022; Pedaste et al., 2021). Students engage actively (hands-on and minds-on) in the learning process with emphasis on observations and experiments as sources of evidence for defensible conclusions (Salchegger et al., 2021)

Context-based learning emphasizes the use of authentic and relevant contexts in which students learn by relating scientific concepts to real-life situations (Rao et al., 2026; Tesfaw & Ayele, 2026), meanwhile ethnoscience-based learning emphasizes cultural contexts by utilizing local wisdom as a learning resource to connect scientific knowledge with the indigenous knowledge (Hadi et al., 2025; Rifa et al., 2025). Scaffolding-based learning emphasizes the teacher's role in facilitating students' learning by providing adaptive and temporary instructional support that is responsive to their needs throughout the inquiry process (Pol et al., 2015; Tatum & Huber, 2020). The I-BATARA learning model shares common principles with these approaches, particularly in promoting meaningful learning, adopting a student-centered orientation, and bridging scientific knowledge with authentic real-world context

Within the I-BATARA learning model, local wisdom provides an authentic and culturally relevant context that connects scientific concepts with students' everyday experiences, thereby promoting meaningful learning and enhancing conceptual understanding. Guided by this context, students engage in inquiry processes involving questioning, investigation, evidence analysis, and evidence-based reasoning, which collectively foster scientific reasoning. Because these inquiry activities impose substantial cognitive demands, adaptive scaffolding is provided through guiding questions, procedural support, conceptual prompts, and feedback to reduce cognitive load and facilitate successful inquiry. The integration of these three components creates a coherent instructional framework in which authentic contexts enhance learning relevance, inquiry promotes scientific reasoning, and scaffolding supports students in constructing scientific knowledge independently, ultimately fostering scientific literacy.

The contribution of the I-BATARA syntax to scientific literacy lies in its systematic alignment between inquiry activities, scaffolding support, and scientific literacy competencies. Each phase is intentionally designed to engage students in authentic scientific practices, ranging from identifying scientifically investigable questions to communicating evidence-based explanations. Consequently, the syntax does not merely organize learning activities but serves as a mechanism for fostering students' ability to explain phenomena scientifically, design and evaluate scientific investigations, and interpret scientific evidence within meaningful local contexts.

The I-BATARA learning model provides practical implications for science teachers by offering a structured framework for implementing inquiry-based learning through culturally relevant contexts. Teachers can implement the model by introducing local wisdom-based phenomena, facilitating scientific investigations, providing adaptive scaffolding throughout inquiry phases, and gradually promoting students' independence in constructing scientific knowledge. The implementation requires supporting resources, including local wisdom-based modules, inquiry worksheets, multimedia resources, and scientific literacy assessment instruments. Furthermore, I-BATARA aligns with contemporary science curriculum objectives that emphasize meaningful learning, scientific reasoning, critical thinking, and the application of scientific knowledge in real-world contexts. From a professional development perspective, the model supports teachers in enhancing their pedagogical content knowledge, instructional design skills, and ability to integrate culturally responsive approaches into science education.

CONCLUSION

Fundamental Finding: There is a need to develop innovative science learning models based on preliminary studies to improve the student’s scientific literacy. The I-BATARA learning model is designed to foster student’s scientific literacy. The I-BATARA learning model consists of six phases, namely: scaffolding based inquiry, problem orientation, investigation, data processing, explanation and conclusion, communication. **Implication:** The I-BATARA learning model can be applied to improve students' overall scientific literacy at various levels of education. **Limitation:** The learning context was limited to batik tulis Tanjung Bumi Madura. **Future Research:** The validity of the I-BATARA learning model model must be established to ensure its effectiveness in classroom implementation.

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