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Article

Exploring the Potential of Jataka Reliefs at Borobudur Temple as a Science Learning Resource on the Topic of the Classification of Living Things

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ABSTRACT

Science learning at the middle school level is often dominated by memorization-oriented practices, resulting in limited connections between scientific concepts and students' everyday experiences. Such conditions may negatively affect students' motivation, engagement, and understanding of scientific concepts. Integrating local cultural resources into science instruction therefore offers a potential approach to creating more contextual and meaningful learning experiences. This study aims to identify the representations of animals and plants portrayed in the Jataka reliefs of Borobudur Temple as a basis for developing a locally contextualized electronic science module (e-module) for learning the classification of living things. A qualitative exploratory research design was employed. Data were collected through structured field observations, photographic documentation, virtual reality (VR) exploration of the temple complex, and a systematic review of relevant literature. The data were analyzed using the interactive model proposed by Miles, Huberman, and Saldaña, which consists of data condensation, data display, and conclusion drawing. The findings revealed 18 taxa of fauna, including mammals, birds, and aquatic organisms, as well as 5 ty of flora depicted in the temple's relief panels. These representations correspond closely with the morphological characteristics of Kingdom Animalia and Kingdom Plantae addressed in the junior high school science curriculum. Based on these findings, the identified cultural representations were incorporated into the initial design of a contextual science e-module for teaching the classification of living things. The study provides a foundation for integrating Borobudur's cultural heritage into science learning while strengthening the contextualization of biological concepts through local cultural resources.

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INTRODUCTION

Science education at the middle school (SMP) level is fundamentally designed to equip students with the ability to understand natural phenomena through meaningful and contextual learning experiences. Among the foundational topics in the middle school science curriculum, the classification of living things holds particular significance because it introduces students to

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the systematic grouping of organisms based on their shared and distinguishing characteristics (Yona & Ilhami, 2022). Mastery of this topic provides an important foundation for understanding biodiversity and the relationships among living organisms (Bilqis et al., 2024; Kurniawan & Hasanah, 2022).

Despite its conceptual importance, however, the classification of living things remains challenging for middle school students. Learning this topic requires students not only to recognize organisms but also to identify and compare their characteristics, describe morphological features, distinguish one organism from another, and determine appropriate classifications based on observable characteristics (Singh & Kala, 2026). These learning processes can be difficult because some classification concepts are relatively abstract and require students to connect observable characteristics with systematic scientific principles. Previous studies have reported misconceptions related to the classification of living things, particularly regarding classification concepts, the use of dichotomous keys, and the rules of binomial nomenclature (Yona & Ilhami, 2022). Difficulties are especially evident when students use dichotomous keys, as they must systematically compare morphological characteristics and make decisions based on specific distinguishing features (Arifin & Anantyarta, 2026; Gultom, 2023). When students are unable to establish these connections, misconceptions may arise and hinder their understanding of classification. Furthermore, low scientific communication skills during the learning of classification can exacerbate these misconceptions, highlighting the need for student-oriented approaches and more engaging learning media (Zulfa & Rosyidah, 2020). Therefore, science learning requires resources that can represent biological characteristics more concretely while providing visual and contextual experiences that are meaningful to students.

One way to provide such experiences is through the integration of local cultural heritage into science learning. Local cultural heritage can serve as a contextual bridge between scientific concepts and students' surrounding environment, particularly when cultural artefacts contain representations of natural phenomena (Septina et al., 2025). In this context, the Jataka reliefs of Borobudur Temple offer an important visual resource because they depict various aspects of flora and fauna within narrative scenes (Lestari et al., 2026). These representations provide opportunities for students to observe biological characteristics directly through visual sources and subsequently connect those observations with the principles of identification and classification.

The integration of local potential into science education is consistent with the contextual nature of local knowledge, which is closely connected to particular cultural and environmental settings (Geertz, 1983). Local potential, including natural resources, indigenous technologies, and cultural heritage, can provide authentic contexts for connecting scientific concepts with students' familiar environments (Rahmaniar et al., 2024; Tiring & O.Janggo, 2026). Previous studies have demonstrated that locally grounded science learning can support contextual learning, critical thinking, conceptual understanding, learning outcomes, student motivation, and appreciation of cultural heritage (Wahyuni & Fawaida, 2024). Thus, the use of cultural heritage in science education is not merely an effort to introduce local culture but can also function as a pedagogical strategy for making scientific concepts more concrete and relevant (B. P. Putra & Wahyuni, 2025; Rahmaniar et al., 2024).

Among Indonesia's diverse cultural heritage, Borobudur Temple provides considerable potential for such an approach. Its relief panels function not only as religious and aesthetic artefacts but also as visual records depicting aspects of natural and social life during the classical Javanese period. Previous research has demonstrated the biological information embedded within these reliefs. Puspitasari (2021), for instance, identified 47 plant species represented in Borobudur relief narratives, including the Jataka and Avadana panels, while Setyawan (2022) demonstrated the potential of temple reliefs for identifying plants from the classical Javanese era. More recently, Putu et al. (2026) reported that Borobudur reliefs can

support locally grounded learning and meaningful student engagement. These findings establish that Borobudur reliefs have considerable potential as visual and contextual resources for science education, particularly through their representations of flora and fauna.

Nevertheless, existing studies have mainly documented the biological representations in Borobudur reliefs or examined their general educational potential, while a systematic mapping of flora and fauna specifically depicted in the Jataka reliefs and aligned with the learning requirements of middle school classification remains limited. Addressing this gap, the present study identifies and maps the flora and fauna representations in the Jataka reliefs and analyzes their relevance to the classification of living things. The novelty of this study lies in linking the biological information embedded in the Jataka reliefs with the conceptual and learning requirements of middle school classification as a foundation for developing a contextual, interactive, and culturally rooted preliminary science module framework. It is important to explicitly state that this study does not aim to empirically test the module's effectiveness in improving learning outcomes, process skills, or cultural appreciation. Rather, it focuses strictly on identifying the biological potential of the reliefs and designing the initial framework of the module.

METHODS

This study employed a qualitative approach with an exploratory research design. The qualitative paradigm was selected because the aim of the study, which is to identify and describe the potential of the Jataka reliefs as a science learning resource, requires in-depth, interpretive examination of visual and textual data rather than statistical measurement. The exploratory design was appropriate given the limited prior literature examining these reliefs as a foundation for science learning materials.

The research proceeded in four phases (Figure 1). To keep the analytical steps distinct, three activities were separated: (1) object identification, which determined which organism a relief depicts on the basis of visual evidence; (2) biological interpretation, which assigned the identified organisms to taxonomic groups and described their morphological characteristics in relation to the junior high school curriculum; and (3) module framework development, which was a pedagogical design activity based on the results of the first two. The study was limited to exploration, identification, and the design of a preliminary module framework. It did not include product validation, field testing, or effectiveness testing, and it is therefore not presented as a full research and development study.

Research Object and Panel Selection

The research object consisted of the Jataka relief panels on the outer walls of the first gallery of Borobudur Temple, Borobudur District, Magelang Regency, Central Java, Indonesia. This cycle comprises approximately 500 panels, with 372 panels in the upper register and 128 panels in the lower register. A total of 21 panels were examined, selected using purposive sampling. A panel was included when it (a) belonged to the Jataka cycle on the first gallery, (b) depicted at least one animal or plant, and (c) was sufficiently well preserved for its morphological features to be recognized. Panels that were heavily eroded, damaged, or obscured were excluded.

Data Collection

Data were collected through four complementary techniques. First, direct observation of the panels was carried out on 27 February 2026 and supported by high-resolution photographic documentation to capture the morphological details of the depicted organisms. Second, to examine panels that were difficult to observe in person and to view the carvings from multiple angles, a virtual reality (VR) tour of Borobudur Temple (the 360-degree virtual tour and VR of Borobudur Temple released by the Directorate General of Buddhist Community Guidance, Ministry of Religious Affairs of the Republic of Indonesia) was used. Third, documentation was carried out using an inventory form that recorded, for each organism, the panel number,

the Jataka story and narrative context, the observable morphological features, and the role of the organism in the story. Fourth, a literature review covered scholarly sources on the Jataka narratives, the biological classification of living things, and locally grounded science learning materials. Previous studies of the Borobudur reliefs, particularly (Maskur et al., 2020) and (Lis et al., 2025), served as key references for cross-verification.

Identification Procedure and Criteria

Identification was carried out collectively by the authors of this article (Annisa Bella Haryanti, Revita Rizky Ariefia, Fatkhi Muffida Putri, and Anjellia Noor Ratditiyan) using the high-resolution photographs and VR images. To ensure accuracy, the associated validation procedure for these identifications relied on rigorous internal validation through a continuous triangulation process involving established biological taxonomies and archaeological literature. A relief was determined to represent a particular organism based on four criteria: (1) overall body form and proportions; (2) diagnostic body parts, such as ears, trunk, beak, wings, feathers, shell, or fins in animals, and trunk, aerial roots, leaves, fruits, or flowers in plants; (3) habitat and ecological setting, such as water, trees, or forest; and (4) narrative context, namely the character or object named in the corresponding Jataka story. Criteria 1 and 2 served as the primary basis, whereas criteria 3 and 4 were used as supporting evidence and were never the sole basis for identification. Each organism was identified to the lowest taxonomic level that the evidence could support, which explains why some entries are reported at the level of family, class, or genus rather than species.

Identification uncertainty was handled in three ways. First, ambiguous carvings were re-examined from different photographs and VR viewpoints and compared with other depictions of the same organism in other panels. Second, the proposed identification was checked against the literature. Third, if the uncertainty could not be resolved, the organism was recorded at a higher taxonomic level or excluded from the inventory.

Biological Interpretation

After identification, each organism was assigned to a taxonomic group using biological references, and its morphological characteristics, as depicted in the relief, were described and linked to the concepts of Kingdom Animalia and Kingdom Plantae in the junior high school science curriculum. The interpretation was based on externally visible traits. Characteristics that cannot be observed directly in the carvings were treated as supplementary content drawn from biological references rather than as findings from the reliefs.

Data Analysis

Data analysis followed the interactive model of (Miles et al., 2014)**,** which consists of data condensation, data display, and conclusion drawing and verification. In data condensation, the observational and documentary data were selected and organized, and the organisms were filtered for relevance to the classification of living things and grouped by taxonomic category. In data display, the condensed data were arranged in classification tables presenting each organism's name, its observable morphological characteristics as depicted in the relief, and its relevance to the concepts of Kingdom Animalia and Kingdom Plantae. Conclusions were drawn and verified through the triangulation procedure described below.

Triangulation

Triangulation was carried out by comparing three types of data: (1) visual evidence from photographs and VR images; (2) iconographic and narrative literature on the Borobudur reliefs and the Jataka stories; and (3) biological references on the morphology and taxonomy of the organisms. Each identification was compared across these sources. An identification was accepted as confirmed when the visual evidence agreed with at least one literature source and was consistent with the biological references. When the sources disagreed, the panel was re-examined, and an identification that remained unresolved was recorded at a higher taxonomic level or excluded.

Development of the Preliminary Module Framework

The identified organisms and their morphological characteristics were then used to design a preliminary module framework, following five stages: (1) mapping learning achievement targets and learning objectives; (2) developing classification content based on the findings; (3) designing contextual learning activities; (4) integrating relief visuals into the module structure; and (5) designing assessment instruments aligned with the objectives. The structure of the framework referred to Putri (Putri et al., 2022). At this stage, the framework remains a design draft. It has not been validated by experts or tested with students, and it is therefore referred to as a preliminary module framework throughout this article. Expert validation, limited trials, and experimental testing are beyond the scope of this study.

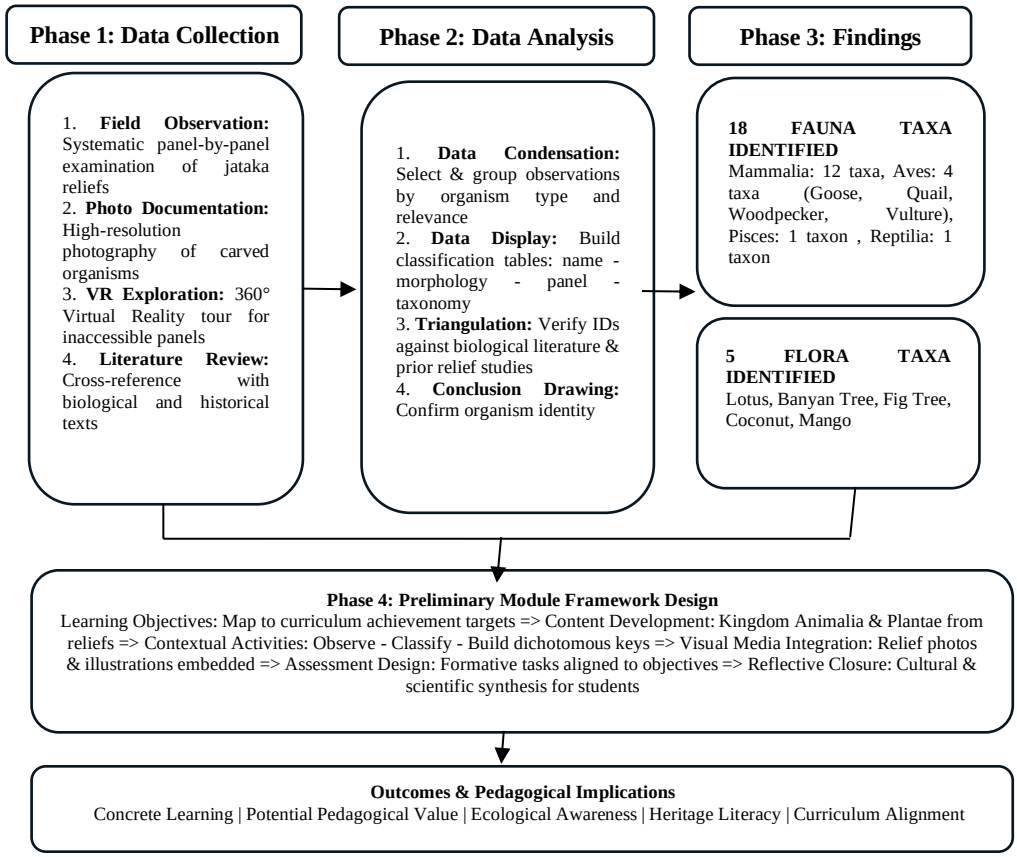


Figure 1. Composite Research Mechanism Illustrating the Four-phase Exploratory Study: Data Collection Methods, Qualitative Data Analysis (Miles et al., 2014), Identification Findings (18 fauna and 5 flora taxa), Module Construction Stages, and Resulting Pedagogical Outcomes

RESULTS AND DISCUSSION

Overview of the Jataka Reliefs at Borobudur Temple

Borobudur Temple

Borobudur Temple is widely recognized as the largest Buddhist monument in the world and stands among humanity's most precious cultural treasures. Its distinctiveness lies in the elaborate stone reliefs that visually narrate key stories and teachings of Buddhism with remarkable artistic and narrative sophistication. Located on the plains of Central Java at Badra wati Street, Borobudur District, Magelang Regency, the temple was constructed using nearly two million volcanic stone blocks arranged across nine tiered levels. Scholars estimate that its construction was completed between the late eighth and early ninth centuries CE, during the height of the Sailendra Dynasty, which held authority over much of Java and Sumatra.

Structurally, Borobudur is organized into three major symbolic zones. The lowest level, Kamadhatu, represents the realm of human desire and depicts the operation of karmic law through the Karmawibhangga reliefs. Above this lies Rupadhatu, consisting of multiple square

terraces filled with relief panels and Buddha statues; this zone contains the Lalitavistara reliefs (depicting the life of Siddhartha Gautama), the Avadana reliefs (illustrating acts of virtue and the principle of cause and effect), and the Jataka reliefs (narrating the Buddha's previous incarnations). The uppermost zone, Arupadhatu, comprises three circular, reliefless terraces adorned with latticed stupas housing Buddha images and crowned by the central main stupa.

Location of the Jataka Relief Panels

In the context of Buddhist sacred architecture, relief carvings serve dual functions: an aesthetic function that beautifies the sacred edifice, and a religious function through which reliefs operate as symbols and signs encoding doctrinal teachings and establishing the religious identity of the architectural work (Pradita & Nugroho, 2020). The Jataka relief panels are located on the outer walls of Borobudur's first gallery, arranged across an upper and a lower register. In total, approximately 500 panels constitute this Jataka cycle: 372 panels in the upper register and 128 panels in the lower register. The narrative sequence begins at the eastern stairway and proceeds clockwise (left-ward from the viewer's perspective on the first level) (Mudra et al., 2019)

The upper register of the outer wall presents reliefs drawn primarily from the Jatakamala a classical collection of Jataka stories rendered sequentially across the first 135 panels, constituting the only Jataka group that can be identified with narrative precision within the sequence. Most individual stories are visualized through three to four panels depicting the key dramatic moments of each tale. These reliefs are regarded as among Borobudur's finest artistic achievements due to the clarity of their compositional detail and the accessibility of their narrative structure.

The Jataka reliefs narrate episodes in which the future Buddha (Bodhisattva) was born into various forms of existence human and animal alike demonstrating moral virtues such as honesty, compassion, self-sacrifice, and care for all living beings. Crucially for science education purposes, these narratives are set within richly depicted natural environments, featuring a wide variety of animals, plants, and ecological settings carved with considerable botanical and zoological detail.

Identification of Fauna (Animals) in the Jataka Reliefs

The systematic analysis of Jataka relief panels yielded the identification of 18 distinct fauna taxa, spanning mammals, birds, and aquatic organisms. Each animal was identified based on observable morphological features as depicted in the carvings, cross-referenced with biological references and prior scholarly research. Table 1 presents the complete inventory of identified fauna, their narrative context, depicted roles, and taxonomic classification relevant to the middle school science curriculum.

Table 1. Fauna Identified in the Jataka Reliefs of Borobudur Temple

No.	Common Name	Scientific Identification	Taxonomic Group	Jataka Story / Panel	Role in Relief
1	Hare / Rabbit	-	Mammalia	The Hare (Śaśa Jātaka)	Bodhisattva born as a noble hare who sacrifices his body upon coals to feed a brahmin.
2	Elephant	*Elephas maximus*	Mammalia	The Elephant; Panel 139, 287	Bodhisattva born as a majestic elephant; also appears as a gifted elephant in Visvantara.
3	Monkey / Ape	Primates	Mammalia	Great Monkey; The Hare; The Buffalo	Bodhisattva as king of the monkeys in a banyan tree; also carries mangoes for the brahmin.
4	Ruru Deer	Cervidae	Mammalia	The Ruru-Deer (Ruru Jātaka)	Bodhisattva as the Ruru deer, speaking with a human voice and teaching Dharma to the king.

No.	Common Name	Scientific Identification	Taxonomic Group	Jataka Story / Panel	Role in Relief
5	Tigress	Felidae	Mammalia	The Tigress (Vyāghrī Jātaka)	Opening story of the Jatakamala; Bodhisattva sacrifices himself to feed a starving tigress and her cubs.
6	Buffalo	*Bubalus bubalis*	Mammalia	The Buffalo (Mahiṣa Jātaka)	A patient buffalo in the forest; a monkey covers its eyes. Bodhisattva embodies forbearance.
7	Jackal / Wolf	Canidae	Mammalia	The Jackal (Śṛgāla Jātaka)	A jackal intimidated by a lion; also depicted as a companion of the hare, bringing milk for the brahmin.
8	Otter	Lutrinae	Mammalia	The Hare	One of the hare's companions; brings seven fish as an offering to the brahmin.
9	Squirrel	Sciuridae	Mammalia	Great Monkey (Panel 86)	Depicted climbing a tree in the scene of the Great Monkey story.
10	Lion	*Panthera leo*	Mammalia	Woodpecker; The Jackal (Panel 133–138)	Lion refuses to repay the woodpecker's kindness; also depicted frightening the jackal; appears beneath a tree in the Hare story.
11	Ram (Male Sheep)	*Ovis aries*	Mammalia	The Hare (Panel 23)	Depicted alongside other animals beneath a tree when Śakra enters the forest.
12	Horse	*Equus caballus*	Mammalia	Śarabha; Panel 287	A king on horseback in the Śarabha story; horse and elephant depicted as royal treasures in Panel 287.
13	Goose / Geese	Anserinae	Aves	The Geese (Haṃsa Jātaka)	Bodhisattva as a golden goose on Lake Manasa; the loyal goose Sumukha refuses to abandon his king.
14	Quail	Coturnidae	Aves	The Quail's Young (Vartaka Jātaka)	Bodhisattva as a quail chick who recites a truth-declaration to extinguish an approaching wildfire.
15	Woodpecker	Picidae	Aves	The Woodpecker (Jalavāhana Jātaka)	A woodpecker removes a bone lodged in a lion's throat, but the lion refuses to show gratitude.
16	Vulture	Accipitridae	Aves	Panel 160	A man and a vulture depicted in a scene in the lower register of the first gallery.
17	Fish	-	Pisces	The Fish (Matsya Jātaka); Panel 138	Bodhisattva born as a great fish; the otter also brings seven fish as offering; fish appear in rivler scenes.
18	Turtle / Tortoise	Chelonia	Reptilia	The Turtle Story (Kūrma Jātaka)	Bodhisattva as a turtle who witnesses a shipwreck and rescues survivors, then offers his flesh as sustenance.



Figure 2. Composite Visual Representations of Identified Fauna in the Jataka Reliefs of Borobudur Temple

As illustrated in Figure 2, the identified fauna collectively represent four major groups relevant to middle school science classification: Mammalia (12 taxa), Aves (4 taxa), Fish (1 taxon), and Reptilia (1 taxon). This finding is consistent with previous research demonstrating the potential of Jataka reliefs as a contextual resource for science learning. Previous research has used Jataka reliefs in digital worksheets for learning the classification of living things, particularly to support students' critical thinking and learning motivation. While the previous study focused on the implementation of a learning medium, the present study focuses on systematically identifying and organizing the fauna representations depicted in the reliefs according to their relevance to junior high school classification learning objectives. Thus, this study provides an empirical basis for selecting and mapping cultural representations for contextual science learning (Saputri & Wibobo, 2025).

Several animals are depicted with recognizable morphological characteristics that support their identification and classification. For example, the elephant panels show prominent ears, a large body, and a characteristic trunk, while the turtle panel presents a distinctive shell structure. The presence of these animals in the Jataka reliefs is also consistent with previous documentation by (I. W. D. Putra et al., 2019) which identified representations of elephants, turtles, peacocks, monkeys, and other organisms across the relief panels. The present study extends these previous observations by examining the observable characteristics of the depicted fauna and relating them to the classification of living things in junior high school science learning.

Beyond their taxonomic utility, the narrative contexts in which these animals appear invest the classification exercise with deeper meaning. Because each animal is presented within a morally significant story, the hare's self sacrifice, the elephant's nobility, and the woodpecker's unrewarded kindness, students encounter these organisms not merely as biological specimens but as culturally embedded beings whose characteristics are meaningful within a shared human narrative tradition. This dual engagement with scientific and cultural content provides a contextual learning experience that connects biological classification with the cultural meanings represented in the Jataka reliefs (Ishep & Rizkil, 2025) ; Wayan Suastra, 2010) .

Identification of Flora (Plants) in the Jataka Reliefs

The analysis further identified 5 distinct plant taxa across the Jataka relief panels. Although the number of identifiable flora taxa is more limited than that of fauna, largely because plants frequently serve as background elements rather than central narrative agents, each identified plant carries significant biological relevance and visual clarity sufficient to support classification learning activities. Table 2 presents the complete inventory of identified flora.

Table 2. Flora Identified in the Jataka Reliefs of Borobudur Temple

No.	Common Name	Scientific Identification	Taxonomic Group	Panel / Story	Role in Relief
1	Lotus	*Nelumbo* sp.	Angiospermae (Dicotyledon)	Various panels; Story IV, XIX (Panel 64–68, 155)	The most dominant sacred symbol. Appears as lotus stems, lotus pools, lotus-throne thrones, and lotus trays. A great lotus grows from the underworld to support a Pratyekabuddha.
2	Banyan Tree	*Ficus benghalensis*	Angiospermae (Dicotyledon)	Great Monkey (Story XXVII)	Monkeys inhabit a great banyan tree overhanging a river; fig fruits falling into the river trigger the king's search for the tree.
3	Fig Tree / Fig	*Ficus* sp.	Angiospermae (Dicotyledon)	Fig story, Panel 100	Fig fruits fall into the river and lead the king to discover the tree; king and fig are depicted clearly in Panel 100.
4	Coconut Palm	*Cocos nucifera*	Angiospermae (Monocotyledon)	Story XXVI, Panels 94–95 (Ruru-Deer)	A prominent figure sits beneath a coconut palm in the scene depicting the Ruru Deer and accompanying men.
5	Mango Tree	*Mangifera indica*	Angiospermae (Dicotyledon)	The Hare (Panel 25)	Monkeys bring mangoes as offerings to the brahmin alongside the other companions of the hare.



Figure 3. Composite visual representations of identified flora in the Jataka reliefs of Borobudur Temple

As shown in Figure 3, the five identified plant taxa collectively represent the two major sub-divisions of Angiosperms (flowering plants) taught in the middle school curriculum: monocotyledons (monocots) and dicotyledons (dicots). The lotus is particularly prominent as a repeated visual and symbolic motif throughout the Jataka panels, appearing in diverse morphological forms that collectively communicate its characteristic growth habit and leaf structure with sufficient botanical clarity.

The banyan tree (Ficus benghalensis) and fig tree (Ficus sp.) are depicted with recognizable features: branching aerial roots, broad canopy structures, and distinctive fruits. These representations allow students to engage with the concept of plant morphology by examining leaf shape, growth habit, and reproductive structures directly from the relief imagery. The coconut palm is rendered with its characteristic tall, single-trunk form and pinnate fronds, providing a clear visual referent for monocotyledonous plant structure. The mango, though less elaborately depicted, is recognizable by its fruit form and provides a point of connection to students' familiar everyday experience, a quality that enhances the contextual relevance of the learning material.

Research by Puspitasari (2021) identified a total of 47 plant taxa across multiple relief narratives at Borobudur, including damar, rubber, and lontar palm in the Jataka and Avadana panels. The present study's more conservative count of 5 plant taxa reflects the focused analytical scope of this investigation: it is restricted to taxa for which visual morphological evidence is clear enough to anchor specific classification learning activities, rather than serving as a comprehensive botanical survey of all relief imagery.

Construction of the Science Module Based on Jataka Reliefs of Borobudur Temple

The identified flora and fauna served as the empirical foundation for designing the conceptual framework of a locally grounded science module. This preparatory instructional design phase proceeded through five systematic stages: (1) mapping of learning achievement targets and specific learning objectives; (2) structuring of classification content grounded in the identified relief findings; (3) design of contextual learning activities; (4) integration of relief visual media into the module's pedagogical structure; and (5) drafting of assessment instruments aligned with the specified learning objectives.

The module was designed to align directly with the Phase D science learning achievement targets (*Capaian Pembelajaran*) mandated by the Indonesian Ministry of Education, Culture, Research, and Technology under the *Kurikulum Merdeka* framework (Kemendikbudristek, 2024). These official targets require students to identify biodiversity among living things, group organisms based on observable characteristics, and apply simple dichotomous keys in classification processes. Each of these competencies is directly addressable through engagement with the flora and fauna depicted in the Jataka reliefs.

The module's substantive content encompasses the following conceptual areas: the defining characteristics of living things; taxonomic hierarchy (kingdom, phylum, class, order, family, genus, species); the five-kingdom and six-kingdom classification systems; binomial nomenclature; dichotomous key construction and application; and the concept of evolutionary kinship. Crucially, each conceptual area is presented in direct connection to the specific flora and fauna identified in the Jataka reliefs, ensuring that abstract taxonomic principles are always anchored to vivid, culturally meaningful visual evidence.

The module's learning activities were designed around observation-based, collaborative, and inquiry-oriented approaches. Students are directed to observe the morphological characteristics of depicted organisms, including body form, locomotor structures, habitat cues, feeding behavior indicators, and other externally visible traits as these features appear in the relief carvings. From these observations, students construct classification groupings based on shared and distinguishing characteristics, engage in comparative analysis across taxonomic groups, and apply dichotomous key logic to systematically place organisms into their appropriate taxonomic categories.

For example, the elephant (Kingdom Animalia, Class Mammalia) can be used to introduce the diagnostic characteristics of mammals: warm-bloodedness, live birth, and mammary glands with the latter two implied through the tigress and cubs narrative panel. The goose and woodpecker panels provide visual anchors for Class Aves (feathers, beaks, bipedal structure, wings). The turtle's depiction supports the introduction of reptiles and their distinguishing characteristics, including scaly integument and a distinctive shell structure. Fish panels provide visual examples for introducing aquatic vertebrates and their distinguishing characteristics. Meanwhile, the lotus, banyan, and mango provide concrete visual examples for exploring the morphological characteristics of Kingdom Plantae, including root systems, stem structures, leaf arrangements, and reproductive organs.

This approach transforms the relief not merely into an illustrative backdrop but into a primary visual source for observing morphological representations. While acknowledging that reliefs are cultural artifacts rather than physical biological specimens, they can allow students to engage in observational and inferential processes relevant to scientific inquiry, such as examining primary visual evidence, identifying shared characteristics, constructing classification categories, and verifying their groupings against biological criteria. This alignment with science process skills, including observation, inference, classification, and communication, provides an alternative to conventional instruction that emphasizes memorization..

The use of Borobudur's Jataka reliefs as a learning context also uniquely enables interdisciplinary connections. This approach offers a theoretical opportunity for students to

learn biological science while encountering Buddhist narrative tradition, appreciating classical Javanese artistic heritage, and reflecting on the ecological worldview embedded in ancient Indonesian civilization. From a pedagogical perspective, such holistic engagement has the potential to foster the development of scientific literacy alongside ecological consciousness and cultural identity. These are dimensions of learning that the Indonesian Merdeka Belajar curriculum framework explicitly values (Latip et al., 2024).

The modular structure follows the systematic framework articulated by Vembriarto (1985) clear learning objectives, content presentation, learning activities, formative assessment, and reflective closure. This structure ensures pedagogical coherence while allowing teachers sufficient flexibility to adapt the module to their specific instructional contexts and students' prior knowledge levels.

Discussion: Significance and Implications for Science Education

The findings of this study provide empirical support for the potential integration of local cultural heritage into science education. By systematically identifying 18 fauna taxa and 5 plant taxa from the Jataka reliefs and mapping their observable characteristics to junior high school learning objectives for the classification of living things, this study provides an empirical basis for developing a locally grounded preliminary science module framework. The findings also offer a practical framework for connecting culturally meaningful visual representations with classification concepts.

A key strength of this approach lies in its pedagogical potential to make abstract taxonomic concepts concrete through cultural artifacts. Classification concepts such as morphological similarity, taxonomic hierarchy, and binomial nomenclature are inherently abstract for young learners. Furthermore, the utilization of these contextual visual resources addresses a fundamental pedagogical issue in middle school science. As demonstrated by Zulfa and Rosyidah (2020) , students' scientific communication skills regarding the classification of living things are often relatively low due to passive learning methods. To overcome this, science education requires student-oriented teaching models and the provision of engaging learning facilities and media, such as interactive student worksheets. The Jataka reliefs are proposed to provide exactly this kind of engaging, meaningful visual scaffolding to prevent misconceptions and stimulate active observation.

The approach also addresses a critical gap identified by Tiring and Janggo (2026) and Purwandari et al. (2022), whose review found that existing implementations of local potential in science learning remain largely confined to generic instructional formats (media, e-learning platforms, encyclopedias, and standardized curriculum documents) that do not leverage Indonesia's specific cultural heritage with the depth and intentionality that the present study demonstrates. The conceptual design of a science module grounded in these findings offers a replicable model for science educators across Indonesia. Heritage sites in diverse regions, such as Prambanan, Dieng, and Trowulan, similarly contain biological and ecological representations that could anchor locally differentiated science learning materials.

Moreover, this study's contribution extends beyond science education narrowly conceived. The use of Borobudur's Jataka reliefs as a science learning resource theoretically supports heritage conservation literacy. When students interact with these reliefs as contextual visual references, they are implicitly invited into a relationship of intellectual stewardship with Indonesia's cultural heritage. However, it is essential to emphasize that the actual impact of this preliminary module framework on students' learning outcomes, science process skills, and cultural appreciation remains to be empirically tested in future experimental studies.

CONCLUSION

This study aimed to identify the animal and plant representations depicted in the Jataka reliefs of Borobudur Temple and to construct them into a foundation for a science module on the classification of living things for junior high school students. Through structured

observation, photographic documentation, virtual reality exploration, and literature-based cross-verification, the study identified 18 fauna taxa, representing Mammalia (12 taxa), Aves (4 taxa), Pisces (1 taxon), and Reptilia (1 taxon), together with 5 flora taxa representing diverse flowering and woody plants depicted in the reliefs. Each organism was identified based on the morphological features visible in the carvings and cross-checked against biological references and previous studies of the Borobudur reliefs.

The identified organisms show relevance to the morphological characteristics of Kingdom Animalia and Kingdom Plantae in the junior high school science curriculum, because externally visible features such as body form, feathers and beaks, shell structure, and the forms of leaves, trunks, and fruits can serve as observable bases for grouping organisms. These findings were then translated into an initial pedagogical framework for a contextual science module, developed through five stages: mapping learning objectives, developing classification content, designing observation-based learning activities, integrating relief visuals, and developing aligned assessments. Accordingly, the outcomes of this study are strictly limited to identifying the potential of the Jataka reliefs as a learning resource and developing a proposed preliminary module framework, rather than producing a tested learning product.

This study cannot establish the effects of the module on science process skills, conceptual understanding, or students' attitudes toward cultural heritage, as no data were collected from students or teachers. Therefore, the module's effectiveness still requires expert validation, limited trials, and experimental research.

Future research should advance from this exploratory foundation to empirically evaluate the effectiveness of the proposed module framework through validation studies, field trials, and quasi-experimental designs measuring learning outcomes, conceptual understanding, and cultural appreciation. Further studies might also extend this approach to other relief sites across Indonesia, establishing a broader, nationally distinctive corpus of heritage-grounded science learning materials.

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