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Ethno-Biomathematics for Junior High School Students' Understanding of Cell Structure: A Case Study

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ABSTRACT

Biology learning at the junior high school level, particularly regarding the structure of plant cells and tissues, is often considered difficult due to its microscopic and abstract characteristics. This study intends to integrate ethnomathematics (the study of mathematical concepts in local culture and environment) as a contextual bridge to facilitate student understanding. We conducted this case study at a junior high school in Wajo Regency, using the Classroom Action Research (CAR) method with a qualitative descriptive design. The research stages include (1) identification of local ethnomathematics; (2) development of teaching materials; and (3) implementation and observation. The findings indicated that the incorporation of ethnomathematics substantially enhanced students' visualization abilities and contextual comprehension. Students more easily internalized the concept of efficient tiling (hexagonal patterns) in plant tissues after analyzing similar patterns found in flora in their surrounding environment. This approach transformed learning into a more active and meaningful one by concretizing abstract material through locally relevant mathematical objects. This study concludes that using native botanical geometric patterns is a creative strategy that shifts the paradigm of biological learning from mere memorization to contextual exploration, while simultaneously improving students' numeracy literacy.

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Introduction

Junior high school education has a major impact on students' scientific literacy (Fauziah et al., 2023; Mayasari, 2023). Biology, as one of the main pillars of science, provides a fundamental understanding of life, the environment, and body functions (Maret & Blower, 2022; Nehm, 2019; Varella, 2018). A solid understanding at the junior high level will lay the foundation for studies in biology, medicine, agriculture, and engineering at subsequent levels of education. The demands of the current Independent Curriculum increasingly encourage contextual, exploratory, and meaningful learning, moving away from rote-centered teaching practices (Asy'arie et al., 2025; Purwandari et al., 2024).

One of the most fundamental and yet most difficult biology topics for junior high school students to understand is cell and tissue structure (Byukusenge et al., 2023; Johann et al., 2025; Vydra & Kováčik, 2025). This difficulty arises from the microscopic (not directly observable) and abstract characteristics of the subjects under examination. In conventional learning, students are often presented with only two-dimensional images, artificial models, or brief observations through a microscope (often limited in availability or quality) (Augusto et al., 2016; Jenkinson, 2018). The effect of this type of learning, which doesn't include visualization or context, is (1) memorization without functional understanding: Students tend to memorize the names of organelles and tissues without understanding how shape (geometry), function, and structural efficiency of cells are all related (Jenkinson, 2018). For example, students know that parenchyma cells are polyhedral, but they don't understand why this shape is the optimal solution in terms of space and diffusion function. (2) Conceptual Alienation: Students fail to see that scientific principles operate in their everyday lives and local environments (Augusto et al., 2016). Science, including biology, is perceived as something separate and existing only in textbooks or laboratories.

Addressing this gap requires a pedagogical approach capable of bridging the abstract world of cells with concrete realities that students can observe and understand: ethnomathematics as a concrete bridge (Eglash, 2023). Ubiratan D'Ambrosio defines ethnomathematics as the study of mathematics as practiced by identifiable cultural groups, including professional groups, indigenous communities, and the public (D'Ambrosio & Rosa, 2017; Frankenstein & Powell, 2023; Rosa, 2023). In the context of science education, ethnomathematics serves as a tool for linking universal mathematical concepts (such as patterns, symmetry, ratios, and geometric shapes) to students' local cultural and environmental contexts (Eglash, 2023; Rosa & Orey, 2017). This approach philosophically recognizes that mathematics is not a static and isolated entity but rather a science embedded in the universe and human activity (Hartoyo et al., 2025; Kabuye Batiibwe, 2024; Laili et al., 2025; Wikasari et al., 2025).

The universe, and especially the world of biology, is a visual manifestation of the purest mathematical principles (Tegmark, 2008). Universal geometric patterns such as bilateral symmetry (in animals), radial symmetry (in flowers), Fibonacci spirals (in seed formation), and tessellations (in cellular tissue formation) are clear evidence that mathematics is the fundamental language of life. By using an ethnomathematics approach, teachers can guide students to search for and discover geometric patterns in local plants around them, apply mathematical concepts (Machaba & Dhlamini, 2021; Owens, 2014; Verner et al., 2019) (e.g., calculating angles, measuring ratios, or identifying tessellations) to the patterns they observe, and connect these mathematical patterns to the biological functions of cell and tissue structures.

Although ethnomathematics has been widely researched in Indonesia (Deda et al., 2024; Lidinillah et al., 2022; Sari et al., 2024; Sunzuma & Umbara, 2025; Turmuzi et al., 2023), most research focuses on (1) Pure Mathematics: Using local culture or architecture to teach geometry and arithmetic concepts. (2) Macrobiology: Using ethnomathematics to teach ecological concepts or macroscopic plant growth patterns (e.g., counting the number of Fibonacci spirals in pinecones).

A critical gap lies in the lack of research that explicitly and in-depth integrates ethnomathematics to understand the microscopic structures of biology, such as cells and tissues. Nevertheless, these basic units of life possess essential geometric patterns. For example, (1) the

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arrangement of parenchyma and epidermal cells often follows a hexagonal or densely packed tiling pattern for space efficiency. (2) The cuticle and cell walls have a layered structure and symmetric patterns that are essential for transport functions.

The absence of a conceptual bridge prevents students from internalizing the relationship between mathematics and biology regarding the fundamental units of life. The urgency of this research is also very high, especially for junior high school students who are in the cognitive development phase moving towards formal thinking but still greatly require concrete media. Junior high school students understand material more easily when presented with real objects (Pujiastuti & Haryadi, 2024; Sinaga & Setiawan, 2022). By using geometric patterns in local plants (for example, a cross-section of a cassava stem, the pattern on a sliced dragon fruit, or a banana leaf) as a concrete analogy, the abstraction of cells can be reduced to a level of understanding that is accessible. Therefore, the application of ethnomathematics guarantees the optimal utilization of surrounding natural resources as learning media (Jacob & Dike, 2023; Pratama & Yelken, 2024; Trisnani & Utami, 2021).

Building upon the gap analysis above, this research offers specific and significant innovations in the field of science education. The key innovation lies in the use of ethnomathematics not only to teach macrobiology (ecology) but also directly as a visual and functional interpretation tool for the microscopic structure of cells and tissues. Furthermore, this research puts forward a model in which geometric patterns found in plants (e.g., the hexagonal pattern of seeds or the tiling of protective tissues) serve as concrete quantitative-geometric analogs to explain why certain cell arrangements (parenchyma or epidermis) are formed as they are—linking form (geometry) to function (biology) and efficiency (mathematics). Additionally, this research produces a learning model that utilizes local natural resources as an "open laboratory." This model is relevant and replicable, especially in schools located in non-urban areas, where access to sophisticated microscopy equipment is often a constraint. Through this integration of ethnomathematics, it is hoped that an understanding of biology will be created that is not only comprehensive but also able to foster students' sense of pride in their local environment and culture while simultaneously strengthening their mathematical reasoning abilities.

Method

Types of Research

This study aims to integrate ethnomathematics through geometric patterns found in local plants to improve junior high school students' understanding of cell structure. The study was conducted as Classroom Action Research (CAR), using a qualitative approach supported by basic quantitative analysis. It took place at Junior High School 2 Sabbangparu, Wajo Regency, South Sulawesi. The site was selected because it offers a natural environment rich in local flora with clear geometric patterns and because students experienced difficulties visualizing abstract biology concepts. The research was carried out over one semester in the 2024/2025 academic year and was implemented in two action cycles. The study adopted the CAR model by Kemmis and McTaggart, which consists of four stages in each cycle: planning, acting, observing, and reflecting. The intervention was concluded once the predetermined success indicators were achieved.

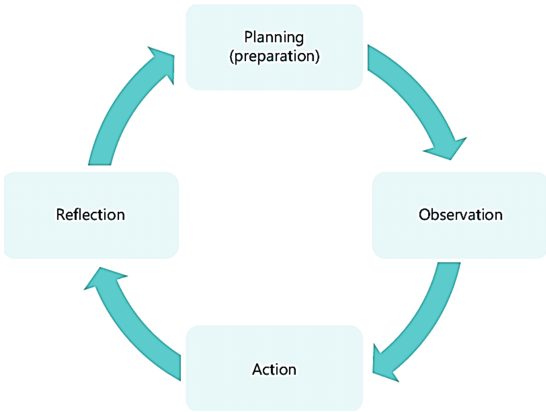

Figure 1. Classroom Action Research Design

Samples

This research was conducted at Junior High School 2 Sabbangparu, Wajo Regency, South Sulawesi. The subjects of this research were 45 seventh-grade students at Junior High School 2 Sabbangparu, who were studying natural sciences on the main topic of classification and organization of life, specifically the subtopic of plant cell and tissue structure.

Data Collection, Instrument, and Procedures

Data was collected through a combination of qualitative and quantitative methods as shown in Table 1.

Table 1. Data Collection Techniques and Instruments

Collection Techniques	Instrument Data	Data Obtained
Written Test (Pre-test and Post-test)	The questions are both multiple-choice and essay-based, with a focus on understanding cell structure and developing visualization skills.	The study utilizes quantitative data to gauge improvements in learning outcomes and understanding.
Observation	The materials include observation sheets for teacher and student activities, as well as a Student Engagement Assessment Sheet.	The study also included qualitative data on the learning process, interactions, and the level of student participation in ethnomathematics exploration.
Interview	The guide for semi-structured interviews with science teachers and student representatives is also included.	Qualitative data was collected to understand student perceptions of the new method and the degree of difficulty in connecting biology and local mathematics.
Documentation	Photos and videos of local plant exploration activities and field notes.	Evidence of activity implementation and the geometric patterns of local plants in Wajo Regency was used.

In Cycle I, the action involved implementing an ethnomathematics module focused on recognizing and identifying basic patterns, such as radial symmetry in local flowers and tessellation patterns in fruit or stem cross-sections, and linking these patterns to basic cell shapes (e.g., parenchyma and collenchyma). The observation stage examined students' activity and engagement and documented their initial understanding of the relationship between geometric patterns and cell function.

In Cycle II, the action increased the complexity of the content by guiding students to analyze the spatial efficiency of hexagonal patterns in epidermal or supporting tissues and

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linking these observations to microscopic structures, including organelle organization. The observation stage focused on students' improved ability to visualize and explain, in functional terms, why cells exhibit particular geometric forms.

Data analysis

Pretest and posttest data were analyzed using descriptive statistics (mean scores and the percentage of learning mastery) and a simple inferential measure (N-Gain) to quantify improvements in students' understanding after the intervention. Observation and interview data were analyzed using Miles and Huberman's interactive qualitative analysis model, which involves data reduction, data display, and conclusion drawing/verification. The study was considered successful if it met two criteria. Quantitative (Learning Outcomes): students' learning outcomes on Cell Structure improved, with an average N-Gain in the moderate to high category (N-Gain $\geq$ 0.30). Qualitative (Process and Engagement): at least 75% of students demonstrated active engagement in the ethnomathematics exploration activities and were able to visualize and explain the functional relationship between geometric patterns in local plants and cell structure.

Research Findings

This section presents the results of Classroom Action Research (CAR) on the integration of ethnomathematics using geometric patterns of local plants to improve the understanding of cell structure in 45 seventh-grade students at Junior High School 2 Sabbangparu, Wajo Regency.

Description of Action Implementation

This research was conducted in two cycles (Cycle I and Cycle II) with a total of 45 participants. The intervention focused on linking concrete environmental objects around Junior High School 2 Sabbangparu, such as a cross-section of a banana trunk, the seed arrangement pattern of a local flower, and the hexagonal pattern on fruit skin, to abstract concepts of cell structure. Cycle I emphasized identifying basic geometric patterns, including symmetry and tessellation, in local plants and using them as analogies for basic cell shapes (e.g., parenchyma and collenchyma). Cycle II focused on analyzing the functional meaning and spatial efficiency of these patterns to help students understand the arrangement of protective tissue (epidermis) and internal cellular structures.

2. Improvement in Learning Outcomes (Quantitative)

Quantitative data were collected through a pre-test and post-test of the cell structure material, conducted before and after each cycle of action (Cycle I post-test and Cycle II post-test), as shown in Table 2.

Table 2. Student Learning Outcomes

Exam	Average Score (100-point scale)	Standard Deviation	Completion Percentage (Criteria for Achieving Learning Objectives ≥70)
Pre-test	48.2	12.5	15.6% (7 students)
Cycle I Post-test	69.5	8.9	64.4% (29 students)
Cycle II Post-test	85.1	6.5	91.1% (41 students)

Understanding Gain Analysis (N-Gain)

To measure the effectiveness of student understanding improvement, the Normalized Gain (N-Gain) calculation was used from the pre-test to the post-test in Cycle II, as shown in Table 3.

Table 3. N-Gain Analysis Results

Calculation	Value	Category
N-Gain	0.71	High

The N-Gain result of 0.71 indicates that the integration of ethnomathematics had a very significant effect on improving students' mastery of the cell structure concept. The drastic increase in completion rate from 15.6% (initial) to 91.1% (final) indicates that this method successfully overcomes the barriers of visualization and abstraction of the material.

Observation Results of Student Engagement

Observations were conducted to measure the level of student activity, initiative, and interaction during the exploration of geometric patterns of local plants.

Table 4. Observation Results of Student Engagement

Observation Aspect	Cycle I (Average Achievement Percentage)	Cycle II (Average Achievement Percentage)
Enthusiasm and Active Involvement	65%	88%
Ability to Identify Local Geometric Patterns	72%	93%
Ability to Make Analogies of Plant Patterns to Cell Structures	68%	90%
Group Collaboration	75%	85%

Table 4 shows a significant increase in Enthusiasm and Active Engagement from Cycle I to Cycle II. Engagement, which reached 88%, indicates that the use of ethnomathematics objects familiar to their environment (local plants of Wajo Regency) made biology learning concrete and relevant. Students did not simply passively view images but actively searched for, measured, and analyzed patterns found in the school environment (for example, analyzing the pattern of bamboo segments or sliced vegetables brought from home). The greatest improvement was seen in students' ability to connect observed patterns with cell structure (analogical). Next, we conducted interviews with five student representatives and the biology teacher to understand their perspectives on the new learning method. The interviews revealed changes in student perceptions, as seen in Table 5.

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Table 5. Student Interview Results

Category	Student Key Quotes	Implications
Concept Visualization	*"I used to be confused when I saw pictures of cells in books, but now when I see a leaf or a slice of fruit, I immediately remember, 'Oh, that looks like a cell structure."*	Local geometric patterns serve as effective visual scaffolding.
Material Relevance	*"So, math is actually found in leaves, huh? I used to study biology on my own and math on my own. Now I understand better why cells must be shaped that way."*	They address conceptual alienation and strengthen functional understanding of cell shape.
Learning Motivation	*"I enjoy learning because I get out of class, looking for objects. So, I don't become bored in class, and the material is easier to absorb."*	They increase motivation and encourage contextual exploration-based learning.

Furthermore, an interview with a biology teacher stated:

"Previously, cell learning was always difficult. Students only memorized the names. With ethnomathematics, they can explain why cells are hexagonal or cubic. They can discuss spatial efficiency and strength, which are deep functional concepts, rather than just memorizing shapes. The limited availability of microscopes greatly aids this method.

The teacher's quote affirms that the successful integration of ethnomathematics bridges the geometric (shape) and functional (biology) aspects, despite the limited facilities at partner schools.

Analysis of Engagement and Contextual Understanding (Qualitative)

Observations during the activities and follow-up interviews with students supported the quantitative results and highlighted two main aspects:

Conceptual visualization skills

Before the activities, many students struggled to visualize how parenchyma and epidermal cells are arranged. After the activities, students showed improved ability to build analogies between observable plant patterns and cellular structures. For example, they linked hexagonal or tiling patterns found in cross-sections of local vegetables or fruit skins to the dense arrangement of protective tissue cells (epidermis). Students were also able to explain that such shapes support space efficiency and protection. In addition, students used radial symmetry observed in stem and root cross-sections to understand the orderly organization of vascular tissues.

Increased Student Engagement

Observation data showed an increase in the average percentage of active student engagement from 65% in Cycle I to 88% in Cycle II. This increase was driven by Local Relevance: Use of ethnomathematics objects from the Kab. Wajo (a local plant) makes learning contextual and engaging, eliminating the impression of biology as a science far removed from everyday life. Exploratory Activities: Exploratory activities (measuring, calculating ratios, and comparing patterns) shift students' roles from recipients of information to active discoverers of concepts.

Research consistently indicates that the incorporation of ethnomathematics serves as an effective pedagogical approach to mitigate the abstraction of cellular structure concepts among students at Junior High School 2 Sabbangparu. The sharp increase in test scores (N-Gain 0.71) was supported by positive behavioral changes (88% engagement) and deeper understanding (evidenced by interviews). The use of geometric patterns of local plants proved to be a relevant and accessible strategy, addressing the shortage of visual aids and microscopic laboratories often experienced by schools in areas such as Wajo Regency. This model successfully transforms biology learning from passive memorization to active, exploratory, and contextual learning, while strengthening students' basic numeracy literacy through the application of geometric concepts in a scientific context.

The success of this CAR lies in the role of ethnomathematics as a concrete bridge connecting abstract entities (cell structures) with real-world geometric patterns. Geometric patterns familiar to students at Junior High School 2 Sabbangparu act as visual scaffolding, enabling students to form mental schemas about cellular organization. These findings support the literature suggest that the integration of ethnomathematics is effective in (a) addressing the challenges of materials requiring spatial visualization and (b) strengthening functional understanding. In this instance, students not only learned that parenchyma cells are polyhedral, but they also grasped that this geometric shape is the best way to store and exchange information, a concept that is not often learned through traditional, picture-based textbook learning. The high N-Gain achievement shows that this method can be used in other schools in Wajo Regency or other places with similar problems getting to advanced lab facilities.

Discussion

The achievement of an N-Gain score of 0.71 (high category) is strong evidence that the integration of ethnomathematics is highly effective in overcoming difficulties in understanding the abstract material on cell structure. This score exceeds the established CAR success threshold, indicating that the use of geometric patterns of local plants from the Wajo Regency environment successfully bridges the gap between microscopic objects (cells) and students' understanding at the junior high school level. Geometric patterns found in local plants, such as the tiling arrangement of fruit/leaf skins or hexagonal shapes, act as visual and concrete analogs for cell structure. Junior high school students, who are still in the cognitive development stage moving towards formal thinking, benefit greatly from this visual scaffolding. The hexagonal pattern in cassava slices, for example, provides a tangible and measurable representation for understanding the arrangement of parenchyma cells, which previously existed only as flat images in textbooks. This integration successfully takes students' understanding beyond simply memorizing shapes. Students can connect geometric shapes with biological functions and mathematical efficiency. For example, they can verbally explain (recorded in interviews) that the tightly packed, hexagonal arrangement of cells is a natural design that is spatially efficient (the principle of tiling) and provides mechanical strength (the principle of geometry). This functional understanding is an indicator of achieving higher-order understanding (HOTS).

Observations showed an increase in the percentage of active student engagement, reaching 88% in Cycle II. This increase is inseparable from the relevance of ethnomathematics in the local context of Junior High School 2 Sabbangparu. Students felt more motivated because the objects of study in biology (plant patterns) originated from their own environment. This aligns with D'Ambrosio's ethnomathematics theory, which emphasizes the importance of cultural and environmental context in the learning process (Aikenhead, 2017; Albanese & Perales, 2020; D'Ambrosio & Rosa, 2017; Prahmana, 2022). Exploring local plants eliminated conceptual alienation, making biology a living science related to their daily lives in Wajo. These findings provide a practical solution for schools with limited laboratory equipment, such as microscopes. The geometric patterns of local plants serve as "visual microscopes" that replace

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the limitations of optical instruments. The use of ethnomathematics thus ensures more equitable access to quality science education, regardless of school infrastructure (Rosa & Orey, 2017).

The success of Junior High School 2 Sabbangparu has several important implications for pedagogical practice in Wajo Regency and in general. Cross-Disciplinary Collaboration: The program requires collaboration between biology and mathematics teachers to ensure that geometric concepts (symmetry, tiling, and ratios) are taught correctly and applied accurately in a biological context. This is a step forward for the Independent Curriculum, which prioritizes the integration of science (Carolina et al., 2024; Syahrial, 2024). Local Curriculum Innovation: These results can serve as a basis for the Wajo Regency Education Office to develop local teaching modules that utilize endemic flora or local cultural patterns as resources for learning ethnomathematics. Teacher Quality Improvement: Biology teachers need to be trained to identify and formulate relevant ethnomathematics patterns in other biology materials (for example, the Fibonacci spiral pattern in phyllotaxis when teaching plant growth).

The research findings bridge a gap in literature, previously dominated by pure ethnomathematics (Deda et al., 2024; Lidinillah et al., 2022; Sari et al., 2024; Sunzuma & Umbara, 2025; Turmuzi et al., 2023). While previous research has demonstrated that ethnomathematics is effective for geometry, such as analyzing the shape of traditional houses for plane figures, this study goes further by proving that this approach is valid for biomathematics, where cultural patterns (ethno) are used to model biological systems (cells) involving the concepts of scale, proportion, and volume (mathematics. The active involvement and deep understanding demonstrated by students indicate that ethnomathematics integration is not just a method but an educational philosophy capable of transforming abstract biology into a concrete, relevant, and measurable science.

Conclusion

The integration of ethnomathematics by geometric patterns from local plants has proven highly effective in enhancing the understanding of seventh-grade students at Junior High School 2 Sabbangparu regarding plant cell and tissue structure. This is supported by a significant improvement in student learning outcomes, with an N-Gain score of 0.71 (high category). This improvement indicates that the method successfully overcomes the barriers to the abstraction and visualization of microscopic material. Geometric patterns found in local plants in Wajo Regency (such as hexagons, radial symmetry, and tiling) serve as powerful concrete analogies. These analogies enable students to contextually connect mathematical forms with the biological functions of cells (e.g., space efficiency), transforming biology from a rote science to an analytical and functional one. Also, there was a big improvement in the quality of the work, with 88% of the students showing high levels of interest and participation. The use of local resources demonstrates that ethnomathematics is a relevant and reliable pedagogical solution for schools with limited laboratory facilities, while also strengthening students' appreciation for the local environment and culture.

As a suggestion, the principal of Junior High School 2 Sabbangparu is advised to adopt and institutionalize this Ethnomathematics Integration Teaching Module as one of the main methods in biology learning on abstract and spatial materials. Biology teachers and mathematics teachers need to establish ongoing collaboration to map and align geometric concepts that can be used in other biology materials (for example, Fibonacci patterns in growth or ratios in ecosystems). Further research is needed to test student knowledge retention over a longer period after the intervention is stopped to validate the sustainability of conceptual understanding. Further research should use an experimental design involving a control group (conventional learning) to compare the effectiveness of ethnomathematics more rigidly. In addition, it is recommended to test the effectiveness of ethnomathematics integration in other junior high school biology materials that also require spatial visualization, such as the cycle of matter or basic genetics.

Conflict of Interest

The author asserts that this article publishing does not present a conflict of interest. Supervisors executed their duties impartially, with no personal, financial, or other affiliations influencing the research or its outcomes. Integrity and transparency were our foremost concerns during the execution and presentation of the research.

Authors' Contributions

M.H. contributed to the development of broad research objectives and aims. I participated in the planning, creation, and presentation of the published work, which encompassed drafting the initial version and conducting substantial translation. I was accountable for overseeing tasks including metadata production, data cleansing, and research data maintenance. I am accountable for executing the research and investigation process, which encompasses conducting tests and gathering data and evidence. F. was accountable for the formulation of the technique, encompassing the development of models. F. was accountable for supplying study materials, instrumentation, and further analytical instruments. The original research group members were accountable for the preparation, creation, and presentation of the published work, encompassing critical review, commentary, and revision during both pre- and post-publication periods. All authors conceived, designed, collected, analyzed, interpreted, wrote, and revised the article. All writers granted their consent to the completed article. The total percentage contribution to the conceptualization, drafting, and correction of this paper is as follows: M.H.: 60% and F.: 40%.

Data Availability Statement

The authors state that the data supporting the findings of this study will be made available by the corresponding author, [M.H.], upon reasonable request

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