Kognitif
Jurnal Riset HOTS Pendidikan Matematika
Volume- 5 No- 4 Page 1724– 1738
ISSN 2776-9704 P-ISSN 2776-9984
https://doi.org/10.51574/kognitif.v5i4.4016

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How to cite: Asih, R. R., Nuzulah, U., & Purnomo, P. (2025). Exploring the School Environment Through an Ethnomathematics Approach. *Kognitif: Jurnal Riset HOTS Pendidikan Matematika*, *5*(4), 1624–1638. https://doi.org/10.51574/kognitif.v5i4.4016

To link to this artcle: https://doi.org/10.51574/kognitif.v5i4.4016

Opened Access Article

Published Online on 20 December 2025

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Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v5i4.4016 Volume 5, No 4, October - December 2025, pp. 1724 – 1738

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Exploring the School Environment Through an Ethnomathematics Approach

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Article Info

Article history:

Received Oct 29, 2025
Accepted Dec 03, 2025
Published Online Dec 20, 2025

Keywords:

Exploration
Ethnomathematics
School environment
Matrix
Contextual learning

ABSTRACT

Mathematics is often perceived as abstract and disconnected from everyday life, causing students to struggle with topics requiring symbolic representation. This situation indicates the need for learning approaches that connect formal concepts with real experiences, highlighting the urgency to address students' limited ability to link symbolic representations with real contexts. This study aims to describe the process and results of exploring the school environment as a source of mathematical representation for matrix topics through an ethnomathematics approach. This research employed a qualitative approach with a case study design. Participants included one mathematics teacher and two 11th-grade students from SMA Negeri 1 Tengaran. Data were collected through observation, interviews, and documentation; instruments consisted of observation sheets, interview guides, and student worksheets (LKPD). Data analysis used the Miles, Huberman, and Saldana model with technique and source triangulation to enhance credibility. The results indicate that environmental exploration helped students identify real-world patterns representable as matrices, such as flowerpot arrangements, floor patterns, and school artwork. The findings also show contributions to mathematical literacy and the Pancasila Student Profile dimensions particularly critical thinking, creativity, and collaboration. The novelty of this study lies in integrating ethnomathematics into matrix concepts, which are rarely examined, and utilizing a modern school environment as a local context. Implications for teaching include replicating exploration steps such as field observation, pattern recording, and matrix representation to support routine lessons or other topics requiring connections between real objects and mathematical structures.

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Introduction

Exploration is an enjoyable activity in which students observe, experience, and directly engage with the learning process (Indari, 2019). The school environment, as part of students' life context, encompasses everything surrounding the school that influences their development, either directly or indirectly. Environmental exploration in the context of mathematics learning involves actively engaging students in observing, identifying, and connecting various objects or phenomena found in the school environment, which are then integrated into the mathematical concepts learned in the classroom. This activity aligns with the principles of contextual learning, which position students' real-life experiences as the basis for constructing knowledge. Utilizing the environment as a medium for exploration allows students to interact directly with their surroundings, enabling them to identify real problems (Rahmadayanti Rabbani et al., 2023). Thus, exploring the school environment has the potential to make learning more meaningful, as students are able to discover connections between the real world and the abstract concepts they are studying.

Mathematics plays a crucial role in education, particularly as a means to enhance the quality of human resources in the global era. However, according to the 2023 Programme for International Student Assessment (PISA) report, Indonesian students' mathematics literacy remains below the OECD average. Indonesia ranked 63rd out of 81 participating countries with an average score of 366, while the OECD average was 472 (OECD, 2023). The abstract nature of mathematics presents a significant obstacle in the learning process, particularly for students with limited prior knowledge (Wathoni, 2024). Many mathematics lessons are product-oriented, leading students to focus solely on solving problems without understanding the underlying concepts (Agustina, 2020). When mathematical concepts are not presented in ways that are contextualized within students' local cultures, they struggle to relate these concepts to their daily lives (Permatasari et al., 2024). There also remains a gap in providing effective solutions to help students understand abstract mathematical concepts (Septiani & Yudhi, 2024). These conditions highlight the need for instructional approaches that can bridge the gap between abstract concepts and students' real-life experiences.

Various instructional approaches have been implemented to address these issues, including contextual approaches that relate learning materials to everyday life (Permatasari et al., 2024), inquiry-based approaches that encourage students to search for and discover concepts (Dalimunthe, 2021), constructivist approaches that provide space for critical and creative thinking (Zidna et al., 2025), and problem-based learning models. While these approaches have proven effective in improving students' understanding, most of them do not explicitly incorporate students' cultural backgrounds or real-life environments as integral sources of mathematical learning.

One instructional approach that aligns well with these needs is the ethnomathematics approach, which serves as an alternative method for helping students understand mathematics through the cultural, traditional, and everyday contexts in which they live (Danoebroto, 2020). This approach emphasizes the relationship between mathematics, culture, and the social environment. Ethnomathematics recognizes that every community has its own ways of thinking about and applying mathematical concepts in daily life. This approach not only highlights traditional cultural elements but can also be adapted to modern contexts, such as school environments where various patterns, shapes, and object arrangements can serve as representations of mathematical concepts (Rosa & Orey, 2011). In the context of this study, exploring the school environment functions as a concrete application of ethnomathematics, as it enables students to construct meaning of mathematical concepts particularly matrices through real-life contexts within their learning environment.

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https://doi.org/10.51574/kognitif.v5i4.4016 Volume 5, No 4, October - December 2025, pp. 1724 – 1738

For example, arrangements of flowerpots, rows of desks in the classroom, or school floor patterns can be mapped into row-and-column structures that represent matrix concepts. In this way, students not only recognize that real objects in the school environment can be depicted or represented mathematically, but they also develop mathematical literacy—the ability to use mathematical concepts to interpret and solve contextual problems (OECD, 2021). Through such exploratory activities, mathematics learning can support the strengthening of the *Profil Pelajar Pancasila*, particularly in the dimensions of critical thinking, creativity, and collaboration, as students work together to observe, discuss, and reflect on their findings from the surrounding environment. In addition, the ethnomathematics approach contributes to the cultivation of cultural values that are relevant in modern school settings, such as environmental awareness, discipline, and a sense of belonging to their learning space. These values form an important part of character education that is integrated within locally contextualized mathematics learning.

Previous studies have reinforced the importance of implementing ethnomathematics in learning. According to Wulansari et al. (2025) ethnomathematics plays a role in improving students' conceptual understanding, motivation, and cultural identity. Lestari et al. (2024) found that the integration of ethnomathematics through Sundanese traditional houses helps students recognize two-dimensional shapes while also increasing their interest in learning mathematics. Research by Hardiarti (2017) and Thalib et al. (2025) also shows that local architectural structures such as temples or fortresses can be utilized as learning resources for geometry. However, most of these studies still focus on traditional cultural contexts. Research that specifically explores modern school environments as a source of ethnomathematics in teaching matrix topics remains limited. Based on this description, this study aims to explore the school environment through an ethnomathematics approach focusing on the concepts of matrices, matrix order, types of matrices, and matrix transpose at SMA Negeri 1 Tengaran. This study is expected to contribute to the development of contextual and meaningful mathematics learning, as well as support mathematical literacy and Profil Pelajar Pancasila.

Method

Type of Research

This study employed a qualitative research design using an intrinsic case study approach (Stake, 1995). This type was selected because the research focused on a specific context—namely, the implementation of school-environment exploration through an ethnomathematics approach in matrix learning at SMA Negeri 1 Tengaran. The case was considered unique because it demonstrated the integration of cultural and environmental contexts into students' mathematical thinking processes. The case boundaries included one classroom, one mathematics teacher, and two eleventh-grade students who were directly involved in the exploratory learning activities conducted in the school environment. The scope of the material covered matrix concepts, matrix types, transpose, and matrix order. The analysis focused on how students constructed mathematical representations from real objects in the school environment within the context of matrix learning. Data were obtained through observation, interviews, and documentation. Data validity was ensured through source triangulation and technique triangulation, while the data were analyzed descriptively through the stages of data reduction, data display, and conclusion drawing (Miles et al., 2014). The intrinsic case study approach was chosen because the aim of the research was not to generalize findings but to deeply understand the cognitive and pedagogical processes that unfolded during the exploration activities (Creswell & Poth, 2018).

Research Subjects

The subjects of this study consisted of one mathematics teacher and two students from SMA Negeri 1 Tengaran who were directly involved in the school-environment exploration learning activities. These participants were selected because they played an active role in the implementation of ethnomathematics-based learning and were able to provide in-depth information regarding their learning experiences in the field. The teacher served as a facilitator who assisted in designing the exploration activities, providing guidance during field observations, and supporting students in connecting real objects with matrix concepts. Meanwhile, the students acted as active participants who conducted direct observations in the school environment, documented real-world patterns, discussed their findings, and constructed matrix representations based on their observations. Prior to conducting the study, the researchers obtained written permission from the school, verbal consent from the mathematics teacher, and participant consent as part of fulfilling ethical research procedures.

Instruments

In this study, the researcher served as the primary instrument, directly responsible for planning, collecting, analyzing, and interpreting the data in the field. Supporting instruments were also employed, including observation sheets, interview guidelines, documentation, and student worksheets (LKPD) to strengthen the findings. The observation sheet was developed based on the syntax of exploratory activities and indicators of students' cognitive engagement in identifying environmental patterns. The interview guidelines were validated through expert judgment by a mathematics teacher. Documentation and LKPD were designed to guide students in identifying environmental patterns and mapping them into matrix forms using rows and columns, and these instruments were validated by the mathematics teacher through readability checks and content alignment with learning objectives. To ensure data validity, triangulation was carried out, including both source triangulation and technique triangulation, by comparing the results of observations, teacher and student interviews, and documentation of the ethnomathematics-based learning activities conducted in the school environment.

Data Collection

The data collection techniques in this study consisted of observation, interviews, and documentation. Observations were conducted to directly examine the learning activities in which students identified matrix components in various structures found in the school environment. These observations took place both inside and outside the classroom. The observation process consisted of three stages. The first stage, orientation, involved the teacher introducing the basic concepts of matrices and then guiding the students outside the classroom to connect matrix concepts with real objects in the school environment. Students were directed to observe predetermined objects. The second stage, environmental exploration, required students to work in groups to document and record the arrangement of objects according to rows and columns, while the teacher acted as a facilitator and guided the process. The third stage, representation and reflection, took place when students returned to the classroom to transform their observations into matrix representations in the worksheet (LKPD) in groups, followed by a discussion with the teacher. Interviews were conducted with one mathematics teacher and two students to obtain in-depth information regarding the implementation of the learning process, perceptions of the environmental exploration activity, and the relevance between the school environment context and the mathematical concept of matrices. Documentation, including photos of activities, field notes, and students' work, was collected as supporting data to strengthen the findings obtained from observations and interviews. Data

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validity was ensured through technique triangulation and source triangulation to increase the credibility of the research results.

Data Analysis

The data analysis process in this study followed three concurrent flows of activity data reduction, data display, and conclusion drawing consistent with the framework proposed (Miles et al., 2014). Data reduction was carried out by selecting, simplifying, and organizing the results of observations, interviews, and documentation in accordance with the focus of the study, namely environmental exploration through an ethnomathematics approach at SMA Negeri 1 Tengaran. The reduced data were then presented in the form of narrative descriptions and images arranged in tables that illustrate how students conducted the environmental exploration activities. The final stage involved drawing conclusions from the emerging patterns observed during the learning process, which were then verified through source and method triangulation. Through this approach, the findings are expected not only to contribute to contextual and meaningful mathematics learning but also to broaden insight into how matrix concepts can be identified, modeled, and applied through real structures and objects found in the school environment. Pedagogically, the process demonstrates that concrete experiences can shift learning from symbolic memorization toward meaningful understanding. When students construct matrix representations from real-world objects, they do not merely recognize mathematical symbols; they also develop their creative thinking skills based on their lived experiences. This indicates that an ethnomathematics-based environmental approach is effective as a bridging tool between empirical experience and formal representation in mathematics learning. This aligns with the perspective of D'Ambrosio (1985) who describes ethnomathematics as a form of mathematical activity arising from human interaction with their environment and culture. According to him, every community has its own ways of understanding, measuring, and modeling the world around them, and these processes constitute mathematical practice within a cultural context. Thus, the environmental exploration activities conducted in this study reflect the application of ethnomathematics as intended by D'Ambrosio using students' experiences and real-life contexts as learning resources that connect local knowledge with formal mathematical concepts.

Research Findings

At the beginning of the activity, the teacher and researcher entered the classroom to provide an introductory explanation of matrix concepts. Afterwards, the students were directed to observe various objects in the school environment, such as arrangements of flower pots, floor patterns, student artwork, woven materials, and the layout of school buildings. Students were divided into small groups of six to seven members and were given exploration worksheets containing observation guidelines, recording columns, and prompting questions related to the connection between real-world patterns and the concepts of rows, columns, and matrix order. This stage marked the initial process of meaning-making, in which students began to relate concrete objects to abstract mathematical concepts. Several students were initially unsure about distinguishing rows and columns in certain patterns; however, group discussions and guidance from the mathematics teacher helped them refine their understanding through argumentation, clarification, and collaborative reasoning.

During the observation process, students explored various areas of the school while recording their findings. They discussed the shapes of patterns, counted the number of elements, and attempted to write matrix representations based on the objects they identified. These interactions demonstrated strong collaborative engagement, with students who had a better understanding assisting peers who were still confused. Meanwhile, the teacher facilitated the activity by posing guiding questions such as what would happen if the order of elements were changed, or what characteristics made a pattern symmetrical. The teacher also documented the activity to record student interactions throughout the process (Observation, 23 September 2025). This process illustrates a transformation in students' ways of thinking, shifting from concrete observations to symbolic representation a hallmark of constructive learning in qualitative educational settings.

Figure 1. Students conducting observations of the school environment

Next, the students discussed their findings within their groups and recorded their conclusions in the worksheet. At this stage, argumentative activities emerged as students interpreted their representations. Several groups debated whether a particular pattern should be categorized as a row matrix or a column matrix. This issue arose because each group observed the object from a different perspective, causing the orientation of the elements to appear inconsistent. In this situation, the teacher acted as a mediator, facilitating the discussion among groups with differing viewpoints and helping students construct understanding based on their own observations.

To provide a clearer overview of the outcomes of the students' exploration activities, the following figures present samples of their worksheet (LKPD) results.

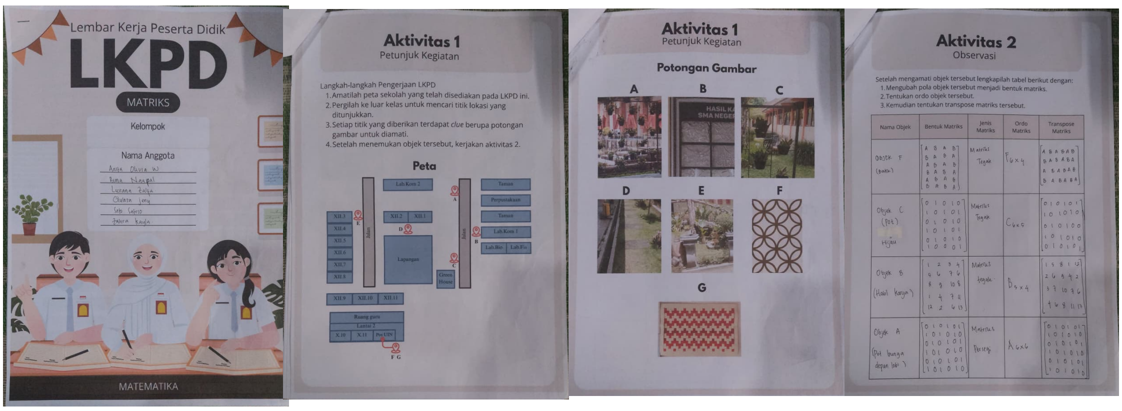

Figure 2. Students' worksheet (LKPD) work

Presented below are the objects in the school environment that students used during the exploration activity conducted through the ethnomathematics approach.

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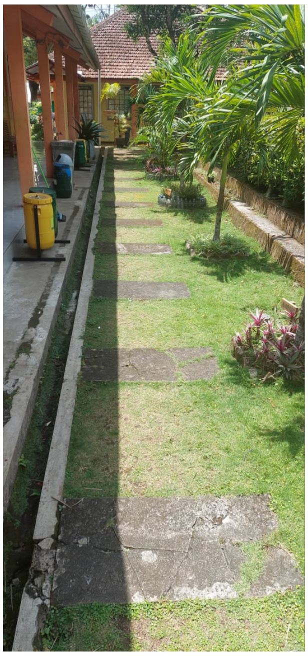
Table 1. Object in School Enviroment

No	Documentation/Image	Matrix Representation	Explanation and Conceptual Analysis
1.	 **Figure 3.** Arrangement of purple flowerpots	$\begin{bmatrix} 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 \end{bmatrix}$	Students marked the flowerpots as the number 1 and the empty spaces as 0. They concluded that the pattern formed a symmetric square matrix (order 6×6).
2.	 **Figure 4.** Arrangement of green flowerpots	$\begin{bmatrix} 0 & 1 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 1 \end{bmatrix}$	Students marked the flowerpots as the number 1 and the empty spaces as 0. Based on the matrix representation, the object has an order of 6×5. This object is classified as a tall matrix, as it contains more rows than columns.
3.	 **Figure 5.** Sink area in the school garden	$[1\ \ 0\ \ 1\ \ 0\ \ 1\ \ 0\ \ 1$	The area containing the sink was assumed to represent the number 1, while the grassy area was assumed to represent 0. The object was represented horizontally. Based on the matrix representation, the object has an order of 1×9, making it a row matrix. However, some groups interpreted the object vertically

4.	 **Figure 6.** Stepping stones in the garden	$\begin{bmatrix} 0 \\ 1 \\ 0 \\ 1 \\ 0 \\ 1 \\ 0 \\ 1 \\ 0 \\ 1 \\ 0 \\ 1 \\ 0 \\ 1 \\ 0 \\ 1 \\ 0 \\ 1 \end{bmatrix}$	The area containing the stepping stones was assumed to represent the number 1, while the grassy area was assumed to represent 0. The object was represented vertically. Based on the matrix representation, the object has an order of 15×1, making it a column matrix. Nevertheless, some groups interpreted the object horizontally.
5.	 **Figure 7.** Students' artwork	$\begin{bmatrix} 1 & 2 & 3 & 4 \\ 5 & 6 & 7 & 6 \\ 8 & 9 & 10 & 8 \\ 1 & 4 & 7 & 11 \\ 12 & 2 & 6 & 13 \end{bmatrix}$	Each identical image was assigned the same numerical value. Some groups used numbers, while others used letters. Based on the matrix representation, the object has an order of 5×4. This object is categorized as a tall matrix, as the number of rows exceeds the number of columns.
6.	 **Figure 8.** Kawung batik pattern	$\begin{bmatrix} 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \end{bmatrix}$	Leaves with left-leaning diagonals were assumed to represent the number 1, whereas leaves with right-leaning diagonals were assumed to represent 0. However, some groups used letters instead: *a* for left-diagonal leaves and *b* for right-diagonal leaves. Based on the matrix representation, the object has an order of 6×4. This object is classified as a tall matrix, as it contains more rows than columns.

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https://doi.org/10.51574/kognitif.v5i4.4016 Volume 5, No 4, October - December 2025, pp. 1724 – 1738

7.	 **Figure 9.** Woven pattern	$\begin{bmatrix}1&0&0&0\\1&1&0&1\\0&1&1&1\\0&0&1&0\end{bmatrix}$	In this image, students identified a repeated matrix pattern of order 4×4 within the woven structure. The red sections were assumed to represent the number 1, while the yellow sections were assumed to represent 0. However, some groups used letters, assigning *a* for the red sections and *b* for the yellow sections. This repeated pattern forms a square matrix.

From these representations, several learning contexts emerged throughout the activity. First, students engaged in symbolic meaning-making through real-world contexts. Here, numbers in a matrix were no longer viewed as empty symbols but as representations of the structures they observed. Symbolic meaning developed through the interaction between concrete experiences and conceptual reflection. Second, students demonstrated a shift in cognitive strategies from rote memorization to meaningful conceptual construction. The exploration process allowed students to move beyond memorizing definitions and instead build understanding through experience. Initial errors, such as misidentifying matrix types, became points of reflection that fostered deeper conceptual growth. Third, collaboration and mathematical dialogue were evident, facilitated through the teacher's open-ended questions that encouraged reflective communication. Students validated each other's answers and corrected misconceptions naturally. Interview results also support these findings. Prior to the activity, students described matrices merely as numbers or letters enclosed in brackets. However, after completing the exploration, their understanding shifted. Students became able to explain that matrices are not just collections of numbers, but representations of positional relationships and structural patterns within a space or object. They also reported that matrices became easier to understand because they could relate the concepts to real objects around the school (Interviews with Bima Naufal Al A'laa and Zahra Kayla Salsabila, 24 September 2025). Consistent with this, the mathematics teacher stated that the exploration activity encouraged students to think more actively and creatively in identifying mathematical applications in everyday life (Interview with Ratna Kusumaningrum, 22 September 2025). Documentation, including photos of student activities and worksheets from other groups, further supports these findings.

Nevertheless, several limitations were encountered during the implementation of this activity. The relatively short exploration time prevented some groups from conducting a deeper analysis of the observed objects. Limitations in documentation tools also resulted in less optimal visual data. In addition, differences in students' perspectives when observing the same object caused variations in the perceived orientation of the elements. However, these limitations did not diminish the value of the findings; rather, they demonstrated that even simple exploratory activities can effectively foster stronger conceptual understanding.

Based on interviews with both students and the teacher, the findings indicate that exploring the school environment through an ethnomathematics approach plays a significant role in transforming matrix learning from something abstract into something concrete, contextual, and meaningful. This activity not only enhanced students' conceptual understanding but also fostered their reflective and collaborative thinking skills, while demonstrating the teacher's effectiveness as a facilitator in creating meaningful learning experiences.

Discussion

The findings of this study indicate that exploration of the school environment can effectively facilitate students' understanding of matrix concepts in a concrete and meaningful way. These results align with Jean Piaget's constructivist theory, which posits that knowledge is actively constructed by learners through direct experience (Suparlan, 2019). In this context, students did not simply receive information about rows, columns, and matrix order; instead, they constructed these concepts through observing real patterns in their school environment. This view is further supported by modern constructivist theories, which assert that knowledge is not transmitted directly by the teacher but is built through the learner's interaction with the learning environment (Glasersfeld, 1995).

These findings are consistent with Pinochet & Cortada, (2022) who emphasize that abstract matrix concepts become easier to understand when connected to concrete experiences and real visualizations. Their study demonstrates that physical representations can enhance students' intuition regarding matrix structures. This direct engagement creates a connection between empirical experience and symbolic representation. As explained by Jerome Bruner, learning becomes more effective when students progress from the enactive stage (direct experience), to the iconic stage (pictorial representation), and finally to the symbolic stage (mathematical notation) (Sundari & Fauziati, 2021). In the enactive stage, students directly observed physical objects such as classroom layouts, seating arrangements, and flowerpot arrangements that exhibited matrix-like patterns. For example, they recorded the number of rows and columns in the flowerpot arrangement and used it as an initial representation of matrix rows and columns. In the iconic stage, they translated their observations into sketches, which were later transformed into matrix diagrams. Finally, in the symbolic stage, students expressed these representations in the form of matrix notation, complete with order and element positions. This process illustrates that mathematics learning becomes more effective when students undergo a gradual transition from concrete objects to abstract symbols, as concrete and visual representations serve as cognitive bridges toward symbolic understanding (Fyfe & Nathan, 2018).

These results also align with the findings of Simonetti et al., (2021) who reported that presenting abstract mathematical concepts through visual experiences including the use of real-world environments can strengthen students' representational understanding. These results are consistent with studies asserting that ethnomathematics plays an important role in bridging cultural contexts with formal mathematical concepts (Rosa & Orey, 2011). The findings also support previous research demonstrating that ethnomathematics-based approaches can enhance conceptual understanding, interest, and student engagement (Amelia et al., 2025). However, the ethnomathematical exploration in this study differs from earlier work that primarily focused on geometry, batik patterns, or three-dimensional structures. For example, Kapitan & Liliana, (2025) examined geometric concepts in Amarasi woven cloth motifs, while Maulida et al. (2025) explored geometric structures in traditional "Bari Pesirah" houses. Whereas geometric contexts emphasize shape and symmetry, matrix exploration highlights structural regularity and positional relationships such as shelf numbering, seating arrangements, or plant rack patterns. Thus, this study broadens the scope of ethnomathematics into the more abstract domain of algebra, an area that has received relatively little attention in previous research. This is in line with international research on Realistic Mathematics Education (RME), which asserts that learning becomes more effective when abstract concepts are connected to real-world contexts (Yuanita et al., 2018). In this sense, the use of the school environment in teaching matrices supports the global principle that mathematical understanding develops through a progression from concrete contexts to abstraction.

https://doi.org/10.51574/kognitif.v5i4.4016 Volume 5, No 4, October - December 2025, pp. 1724 – 1738

Furthermore, the findings of this study reinforce the principles of Contextual Teaching and Learning (CTL), which emphasize that authentic experiences can deepen conceptual understanding (Damyanti et al., 2025). This aligns with research indicating that contextual learning helps students connect new knowledge with real-world experiences (Berns & Erickson, 2001). The exploration of real objects demonstrated that the school environment—particularly at SMA Negeri 1 Tengaran—contains numerous structures that can be represented in the form of matrices. Linking these real-world objects to mathematical concepts allowed students to connect new knowledge with their existing cognitive structures. This is consistent with Ausubel's assertion that new knowledge is more readily understood when it is anchored to learners' prior cognitive structures (Ekawati, 2017). Additionally, such processes of connection enhance memory retention and deepen conceptual understanding (Novak, 2010). Through this approach, the abstract concept of matrices becomes easier to grasp because it does not appear as a detached, purely symbolic idea instead, it emerges from concrete situations that students regularly observe and experience.

Additional international support comes from Kleshnina, who emphasizes that connecting mathematics to real-world contexts enhances both motivation and understanding, even for highly abstract concepts. This indicates that matrix learning grounded in environmental exploration aligns with global trends in meaningful mathematics education (Kleshnina et al., 2025). In classroom practice, this approach was implemented through a field-based exploration task. Each student group was asked to identify objects that could be represented as matrices, sketch the rows and columns based on the observed patterns, and then construct matrix notation using specific elements such as color, size, shape, or the presence of an object. This activity prompted discussions among students regarding differences in interpreting the elements and encouraged them to construct concepts independently. Through this process, students became more active, enthusiastic, and capable of linking theoretical ideas with real-world contexts.

However, the implementation of this approach also encountered challenges, particularly differences in the answers recorded in the worksheets across student groups, especially in determining the type of matrix. For example, one group identified a particular object as a row matrix, while another group classified the same object as a column matrix. These discrepancies occurred because each group observed the object from a different perspective, resulting in variations in how they identified elements and categorized matrix types. Such differences in observational focus led to outcomes that were not always uniform across groups.

In addition, this approach cannot be used effectively to introduce the concept of matrix transposition, as the real-world object patterns observed by students cannot always be reversed between rows and columns without altering their physical form. Therefore, environmental exploration is more suitable for introducing basic matrix concepts but is less effective for teaching more advanced operations such as transposition. This approach also supports the development of 21st-century competencies. Activities such as identifying patterns, classifying elements, and converting real-world objects into matrix notation foster students' critical and logical thinking skills (Wahyuni & Kusaeri, 2024). The process of designing representations, determining element categories, and selecting appropriate objects encourages creativity. Group discussions and presentations of exploration results further strengthen students' communication and collaboration skills. Thus, in addition to enhancing conceptual understanding, this ethnomathematics-based environmental exploration approach contributes to the development of 21st-century learner profiles. Overall, these findings have important implications for mathematics teaching strategies in secondary schools. Teachers can utilize the surrounding environment as a contextual and relevant learning resource that also serves as a bridge to abstract concepts such as matrices. This approach not only strengthens conceptual understanding but also enhances motivation and students' sense of ownership in mathematics, as they become aware of the presence of mathematical concepts in their daily lives. Moreover, this approach expands the application of ethnomathematics from the domain of geometry to the domain of algebra.

Conclusion

This study demonstrates that exploring the school environment through an ethnomathematics approach effectively supports students in understanding matrix concepts in a more concrete and meaningful way. Its effectiveness lies in the fact that students construct the concepts through direct observation of objects that exhibit matrix-like patterns, allowing them to personally experience the process of representing concrete objects into symbolic notation. The key components that most strongly contributed to students' understanding were the direct observation activities and the transformation of observational results into matrix form, which enabled students to connect empirical experiences with abstract concepts in a more relevant and coherent manner. These findings broaden the application of ethnomathematics to algebraic content and reinforce contextual learning theories suggesting that authentic experiences can enhance the understanding of abstract concepts. This approach also offers significant pedagogical contributions by fostering positive attitudes toward mathematics and strengthening collaboration as well as 21st-century skills. Despite its positive impact, this study has methodological limitations, including a limited number of participants and a context-specific school environment. Therefore, caution is needed when generalizing the findings, and the approach may not yet be optimal for teaching more advanced matrix topics. Practically, teachers can apply similar exploratory activities in other classes and for different topics, such as geometry. Teachers can also use objects in the school environment as tools for building concepts progressively in accordance with students' cognitive development. Thus, this study affirms that ethnomathematics-based environmental exploration has strong potential to serve as an alternative learning approach that is conceptual, meaningful, and relevant to 21st-century education. It also opens opportunities for developing more innovative instructional models in the future.

Acknowledgments

The authors would like to express their gratitude to SMA Negeri 1 Tengaran for granting permission and providing the facilities necessary for conducting this research. Appreciation is also extended to all individuals who contributed information, guidance, and support throughout the data collection process, enabling this study to be carried out successfully.

Conflict of Interest

The authors declare that there is no conflict of interest.

Authors' Contributions

R.R.A. contributed to designing the study, developing research instruments, collecting data, analyzing and processing data, and preparing the research discussion. U.N contributed to designing the study, generating the initial research ideas, collecting data, analyzing and processing data, and preparing the research discussion. P conducted the final revision of the manuscript and approved the final version. All authors declare that they have read and approved the final version of this manuscript. The total contribution percentages from the beginning to the end of the study are as follows: R.R.A.: 35%, U.N.: 35%, and P.: 30%.

Data Availability Statement

The authors declare that the data supporting the findings of this study will be made available by the corresponding author, U.N, upon reasonable request.

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