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Research Article

Didactical Situations in Ethnomathematics Learning: A Case Study on Addition, Subtraction, Integers, and Fractions Using Sundanese Traditional Games

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ABSTRACT

The purpose of this study is to analyze the didactical situations experienced by elementary school students when learning mathematics through traditional games. The traditional game examined is the egg game from Sundanese culture in West Java, Indonesia. This qualitative study involved 524 students from grades 1 to 6 in elementary school and grade 1 in junior high school during the initial stages of didactical design. The revised didactical design stage involved 304 elementary school students. Data collection instruments included learning obstacle tests, worksheets, documentation, and observations. The findings revealed epistemological obstacles in understanding mathematical concepts such as addition, subtraction, integers, and fractions. Through iterative didactical design and revisions, ethnomathematics-based teaching materials incorporating the egg game were developed, demonstrating alignment between teacher predictions and student responses. The results suggest that traditional games can serve as effective tools to make mathematics learning more engaging, accessible, and culturally relevant.

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INTRODUCTION

Mathematics learning in primary schools can be enhanced through culture-based approaches, one of which is ethnomathematics. Ethnomathematics integrates mathematical concepts with cultural perspectives, enabling students not only to understand and appreciate their own cultural heritage but also to respect the cultures and practices of others. Research has shown that the integration of cultural elements into mathematics education, such as the legacy of Confucian culture in the mathematics classroom, positively impacts students' understanding and engagement (Schultes & Shannon, 1997; Simamora et al., 2018; Sum &

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Kwon, 2020). By linking mathematics with culture and local traditions, educators can address the diverse cultural backgrounds of students and promote meaningful learning (d'Entremont, 2015).

This study examines the intersection between mathematics and Sundanese culture in West Java, Indonesia, through the lens of ethnomathematics. Specifically, it explores the traditional game **endog-endogan** (egg game) as a tool for teaching mathematical concepts. Sundanese culture is deeply rooted in the population of West Java, Indonesia, which represents the second-largest ethnic group in the country, with approximately 48 million people in 2018. Predominantly Muslim and highly community-oriented, the Sundanese maintain rich traditions that include unique cultural practices and games.

Anthropological studies suggest that Sundanese culture has Austronesian origins, tracing its roots to Taiwan and arriving in Java around 1,500 to 1,000 BC (Bellwood, 2008; Roosita et al., 2008; Blust, 2013). Within Sundanese society, there are traditional rural communities, known as **kampung adat**, that preserve ancient customs and way of life. These communities often reside in remote villages across West Java, offering a living example of cultural heritage. This study highlights how such cultural traditions can serve as an innovative medium for teaching mathematics in primary schools, fostering not only cognitive but also cultural and social development among students.

Figure 1. Sundanese culture from western Java, in Indonesia.

According to Supriadi (2019), Sundanese ethnomathematics refers to the application of cultural practices and perspectives rooted in Sundanese traditions to develop mathematical thinking. It emphasizes the idea that mathematics is a product of culture, shaped by the practices, values, and vision of the Sundanese community.

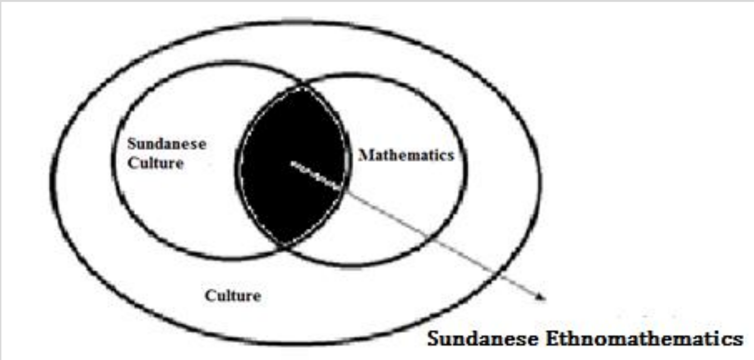

Figure 2. Sundanese Ethnomathematics Concept (Supriadi, 2019)

Sundanese Ethnomathematics Learning

Benda-benda dan alat-alat yang dapat membantu siswa memahami apa yang mereka pelajari sangatlah penting mengingat kesulitan yang ada saat ini. Di sini, siswa memerlukan materi dan alat dalam kehidupan nyata untuk membantu mereka memahami cara menerapkan apa yang mereka pelajari di kelas sains. Oleh karena itu, untuk meningkatkan pendidikan sains dan memfasilitasi pembelajaran lebih cepat, diperlukan media yang dapat meningkatkan keterlibatan siswa dan hasil belajar. Delapan siswa kelas enam laki-laki dan delapan perempuan, bersama dengan instruktur mereka, berpartisipasi dalam penelitian ini.

Sundanese ethnomathematics learning aims to enhance the mathematical thinking of primary school students by integrating cultural contexts into the learning process. This approach prioritizes the development of creative and critical thinking skills, leveraging the Sundanese cultural background as a framework to encourage students to think innovatively in mathematics. The results of studies by Achor et al. (2009) and Verner et al. (2019) support the effectiveness of ethnomathematics in advancing students' understanding, particularly in geometry. This study seeks to optimize teaching resources by designing learning materials aligned with Sundanese ethnomathematics, particularly through the use of the traditional **endog-endogan** game.

Ethnomathematics

Ethnomathematics refers to the mathematics that emerges within specific cultural contexts, offering an alternative to traditional methods of teaching mathematics (Cimen, 2014). Ubiratan D'Ambrosio, the pioneer of ethnomathematics, has positioned it as a vital subfield of mathematics education, emphasizing its potential to bridge cultural heritage with mathematical learning. This study introduces an innovative approach by adapting Sundanese cultural elements to align with mathematical concepts, thus enriching students' mathematical creativity.

Through ethnomathematics, teachers can integrate cultural ethics into the learning process, providing a more relatable and meaningful context for students. After implementing this approach, teachers evaluated the alignment between their instructional plans and actual learning outcomes by analyzing students' obstacles in understanding mathematical concepts. These reflections informed necessary revisions to teaching materials, resulting in improved learning resources.

According to D'Ambrosio and D'Ambrosio (2013), ethnomathematics represents the mathematical knowledge and practices inherent to distinct cultural groups, addressing real-life problems through culturally developed techniques. In education, the ethnomathematical approach bridges learners' cultural practices with conventional academic mathematics (Rosa & Orey, 2010).

Ethnomathematical learning allows students to understand how mathematical ideas are expressed and applied in their own culture and others. This approach makes conventional mathematics more comprehensible and emphasizes its relevance, beauty, and utility (Achor et al., 2009). Students gain insight into how mathematics is applied in daily life, thereby enhancing their ability to interpret mathematical concepts and broadening their overall understanding of mathematics (Begg, 2001).

Ethnomathematics enriches the mathematics curriculum in multiple ways. It helps students grasp abstract mathematical concepts (Owens, 2014), fosters engagement and creativity (Massarwe et al., 2011), and improves motivation and attitudes toward mathematics (Shirley, 2001). Additionally, it enables educators to promote cultural awareness and inclusivity by linking mathematics to students' cultural identities (Rosa & Orey, 2010).

From a pedagogical perspective, the cultural context of ethnomathematics allows teachers to nurture students' understanding of their own and other cultures (D'Ambrosio & D'Ambrosio, 2013). This approach supports the development of multicultural awareness, ethical values, and cultural identity (Gerdes, 1998). Furthermore, this research applies the theoretical and analytical framework of the Theory of Didactic Situations (Brousseau et al., 2004) to explore the long-term effects of ethnomathematics learning on elementary students. While TDS has often been used for single-class studies, this research expands its application to diverse groups of students, illustrating its potential for broader implementation.

This study is grounded in the **Theory of Didactical Situations (TDS)**, as described by Artigue (2015). TDS examines the effectiveness of didactical systems, emphasizing the identification of regularities and their transformation into didactical phenomena. It focuses on the creation of fundamental situations associated with specific mathematical concepts and their actualization into didactical situations while considering the constraints and contexts of particular educational settings. TDS also explores the interrelation between situations and the development of knowledge within specific domains, with careful attention to adaptation and acculturation processes (Artigue, 2015).

In this study, TDS provides the framework for designing and analyzing fundamental situations for teaching addition, subtraction, integers, and fractions through ethnomathematics-based traditional games. The broader aim is to identify the regularities within ethnomathematics learning (EL) as a system of didactical situations.

TDS posits that optimal learning situations can be created when students are placed in carefully designed scenarios where achieving specific goals requires them to reconstruct or discover mathematical concepts using their prior knowledge (Brousseau et al., 2004).

Brousseau et al. (2004) outline the didactical process as a sequence of situations divided into three main categories:

1) Situation of Devolution
   In this phase, the teacher encourages students to take responsibility for their learning. The teacher relinquishes some control over justifying, guiding, and correcting students' actions, shifting these responsibilities to the **milieu**—the system within which students interact during the a-didactical situation. The milieu includes learning resources, necessary information, tasks, interactions with peers, and other elements critical to the learning process (Artigue, 2015).

2) Mathematical Situation

In this phase, students engage in self-directed mathematical activities. These include making conjectures, evaluating their validity, formulating and testing hypotheses, deriving results, discussing ideas, constructing arguments and proofs, and assessing the consequences of their decisions. The design of this situation ensures that proper management of the milieu leads students toward the intended mathematical goal (Brousseau et al., 2004).

3) Situation of Institutionalization

In this final phase, the teacher identifies and formalizes the students' knowledge that aligns with standard mathematical solutions. This phase consolidates students' understanding, preparing them for future mathematical challenges (Brousseau et al., 2004).

The **milieu** plays a central role in TDS. While interacting with the milieu, students share and expand their current knowledge, challenge their limits, and develop new strategies. However, mere adaptation to the milieu is insufficient. The learning process also requires **acculturation**, wherein students integrate knowledge gained through interaction with the milieu into formal mathematical structures recognized in the discipline (Brousseau et al., 2004).

By applying TDS, this study aims to design effective didactical situations through the traditional **endog-endogan** game, enabling students to explore mathematical concepts in a meaningful and culturally relevant context. The teacher's role is to facilitate the interplay between students, the milieu, and the mathematical goals, creating a structured yet flexible environment for learning.

RESEARCH METHODS

The participant research subjects used in learning obstacle test are the fifth until sixth-grade elementary school and junior high school students with a total of 524 students. After obtaining Learning obstacle data, then continued on the initial didactic design stage of compiling a student worksheet which adapted to Sundanese ethnomathematics learning with endog-endogan games, design stage of initial didactic of the first until six grade students in a elementary school with a total of 152 students. After the initial didactic design obtained revised learning obstacle by reconstructing a students worksheet and revision of didactic design using the first until sixth-grade students in other class with a total of 152 students.

Learning Process

The *endog-endogan* game is a traditional Sundanese game. This game is simple to take part in for the reason that it simply used one hand as the media for the game. Therefore, this game is extremely supple to be played wherever and anytime. One of the repayment to be cultured from this game is that the students should collaborate with every one other to construct-up to a mountain, and if they reduce, they must always give confidence to each other to rebound back once more.

Figure 3.Endog-endogan game with the subtraction concept

Example Sundanese ethnomathematics learning in a subtraction operation is as follows:

prepared questions in going forward for the student;
the inscription the questions on the board or worksheet, speak 6-2 = ...
prepared three children by clenching their hands as if they are eggs.

Data Analysis

This study employed a qualitative approach using the **Didactical Design Research (DDR)** method as described by Hudson (2008) and Suryadi (2013). The analysis focused on the development of knowledge materials for Sundanese ethnomathematics learning.

Data Collection Techniques

The following techniques were used to collect and analyze data:

1) Learning Obstacle Test**:**
    - The test was designed to identify specific challenges faced by students in understanding mathematical concepts such as subtraction, fractions, and integers.
    - Data from the test were used to construct an initial didactic design.
2) Initial Didactic Test**:**
    - Teaching materials were piloted to evaluate their effectiveness in addressing identified learning obstacles.
3) Revised Didactic Design**:**
    - Based on the outcomes of the initial test, teaching materials were refined and re-evaluated in a different group of students.
4) Interviews**:**
    - Teachers and students were interviewed to gather qualitative insights into their experiences with the learning materials.
5) Observations**:**
    - Classroom interactions and student engagement were observed to assess the practical application of the teaching materials.

Data Analysis Process

Student responses to the learning obstacle test were analyzed using the following categories:

1. **Aligned with Predictions**: Responses that matched the researchers' forecast, indicating correct understanding of the concepts.
2. **Partially Aligned with Predictions**: Responses that showed partial understanding, with minor errors or misconceptions.
3. **Not Aligned with Predictions**: Responses that deviated significantly from expectations, indicating a need for further instructional intervention.

Implementation in Didactic Design

- The data collected from the initial learning obstacle test informed the creation of culturally relevant teaching materials using the **endog-endogan** game.
- The iterative process involved revising the didactic design to address specific learning challenges identified during the implementation.
- Observations and interviews provided additional context, allowing researchers to refine materials and ensure their alignment with students' needs and cultural backgrounds.

By categorizing responses and iteratively refining the teaching materials, the study successfully developed a culturally integrated didactic approach to enhance students' understanding of mathematical concepts.

RESEARCH RESULTS AND DISCUSSION

Results

Results of the Design Stage *(Design)*

This section presents the findings of the study, organized into three main stages: identification of learning obstacles, implementation of the initial didactical design, and evaluation of the revised didactical design. These results are then discussed in relation to the theoretical framework, previous research, and pedagogical implications.

1. Identification of Learning Obstacles

The learning obstacle tests revealed significant challenges encountered by students across various mathematical concepts and grade levels.

1) Subtraction (Grades 1–3)**:**
   Students in lower grades exhibited difficulty in distinguishing between addition and subtraction operations, particularly when problems were presented in narrative form. For example, in the question, "Udin made eight cakes, but one was burnt. How many cakes are left?" many students struggled to identify subtraction as the correct

operation. These difficulties suggest a lack of understanding of basic arithmetic operations and highlight the need for more concrete learning tools.

2) Fractions (Grades 4–5)**:**

Challenges with fractions were prominent among students in intermediate grades. A common misconception was the tendency to add both numerators and denominators directly e.g.,frac $\frac{2}{4}+\frac{3}{4}=\frac{5}{8}$. Additionally, students found it difficult to relate fractions to real-life contexts, making it harder for them to conceptualize the operations.

3) Integers (Grade 6)**:**

At the upper elementary level, students faced challenges with negative integers. For instance, many misinterpreted −13+5=13 + 5, ignoring the negative sign. This indicates a gap in understanding the properties of integers, particularly in operations involving both positive and negative numbers.

These findings informed the development of the initial didactical design, which incorporated the **endog-endogan** game as a culturally relevant tool to address these learning obstacles.

2. Implementation of the Initial Didactical Design

The initial didactical design incorporated Sundanese ethnomathematics through the **endog-endogan** game. This game provided a culturally familiar and interactive medium for students to explore mathematical concepts.

1) Subtraction**:**

Students demonstrated better conceptual understanding when subtraction was contextualized using the **endog-endogan** game. In this activity, students physically represented numbers using clenched fists (as "eggs") and removed "eggs" to simulate subtraction. For instance, in solving 26−2, students "cracked" two eggs to find the result. This tangible and engaging approach helped make abstract concepts more accessible.

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2) **Fractions**:

   Although the game increased student engagement, challenges with fractions persisted. While some students demonstrated improvement in solving simpler problems, such as $\frac{2}{4}+\frac{3}{4}=\frac{5}{4}$, the majority required additional guidance to fully grasp the concept of common denominators.

3) **Integers**:

   For integers, the game provided limited support in helping students differentiate between positive and negative values. Students often relied on rote memorization rather than conceptual understanding, indicating the need for further refinement of teaching materials.

Overall, the initial design showed promise in enhancing student engagement and collaboration, with notable improvements in subtraction. However, persistent challenges with fractions and integers necessitated revisions to the didactical design.

3. Evaluation of the Revised Didactical Design

The revised didactical design incorporated feedback from the initial implementation, focusing on addressing specific learning obstacles.

1) Fractions**:**

   The revised design introduced more explicit visual aids within the **endog-endogan** game. For example, students used visual representations, such as partitioned diagrams, to better understand fraction addition. This adjustment resulted in significant improvement, with most students solving problems such as $\frac{2}{4}+\frac{3}{4}=\frac{5}{4}$ correctly. Students were also able to explain the process verbally, demonstrating a deeper understanding.

2) Integers**:**

   To address challenges with integers, the game was modified to include representations of negative and positive values. For instance, "missing eggs" were used to symbolize negative numbers, while "intact eggs" represented positive numbers. This approach clarified the concept of combining positive and negative integers, enabling most students to solve problems like −13+5=−8-13 + 5 = -8−13+5=−8.

3) Subtraction**:**

Improvements in subtraction were sustained in the revised design. Students consistently solved subtraction problems, such as 720−257=463 with greater accuracy and confidence. The game-based approach not only supported their understanding but also reduced anxiety associated with large numbers.

Teachers reported a substantial alignment between predicted and actual student responses during the revised implementation. The majority of students demonstrated increased accuracy and engagement, validating the effectiveness of the refined design.

DISCUSSION

This study analyzed how didactic situations in mathematics learning can address learning obstacles encountered by students in grades 1 through 6. According to the Theory of Didactical Situations (Brousseau & Warfield, 2020), learning obstacles, particularly epistemological barriers, arise due to the limited prior knowledge students possess in specific contexts. The findings align with previous studies (Turk & Arslan, 2012; Modestou & Gagatsis, 2013), which emphasized the importance of designing learning activities to overcome these barriers.

Analysis of Learning Obstacles

The learning obstacle test identified challenges unique to each grade level, as summarized below:

1) **Grade 1**: Students struggled with distinguishing between units, tens, and hundreds in numerical systems, similar to findings by Wong & Chan (2019). Long word problems further exacerbated these difficulties, as students found symbolic representations easier to interpret. The challenges were consistent with research by Phonapichat et al. (2014), which highlighted students' lack of motivation to read long mathematical texts.
2) **Grade 2**: Students showed difficulty modeling story problems into mathematical expressions. While they could replicate examples, they struggled to create problems independently. This reliance on templates limited their cognitive flexibility in mathematical reasoning.
3) **Grade 3**: Students faced challenges in subtraction, particularly when subtracting larger numbers from smaller ones. This suggests a need for visualization strategies, as recommended by Kinda (2013) and Peters et al. (2014), who observed similar difficulties in their studies.
4) **Grade 4**: Many students misunderstood the concept of fractions, incorrectly adding numerators and denominators directly. These misconceptions, also reported by Ciosek & Samborska (2016), indicate a fundamental gap in students' conceptual understanding of fractions.

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5) **Grade 5**: The challenges with fractions persisted in Grade 5, particularly in story problems. Students continued to make errors in adding fractions, failing to recognize the importance of finding a common denominator.
6) **Grade 6**: Students exhibited difficulties in comparing and ordering integers. They often treated negative integers as if they were positive, a misconception that aligns with findings by Whitacre et al. (2017).

These learning obstacles underscore the need for innovative instructional approaches to bridge the gap between students' prior knowledge and mathematical concepts.

Initial Didactical Design with Endog-Endogan Game

To address these challenges, an **Initial Didactical Design (IDD)** was implemented, incorporating the traditional Sundanese game **endog-endogan**. This approach aligns with Simon et al. (2018), who emphasized the importance of designing meaningful learning trajectories. In this study, the endog-endogan game was modified to encourage students to explore mathematical concepts actively.

1. **Design and Implementation**:

   The IDD used the endog-endogan game to create hands-on learning experiences. For example:

   - **Subtraction**: Students visualized subtraction by physically removing "eggs" from a group. This helped them understand the concept as a tangible process.
   - **Fractions**: The game was adapted to demonstrate partitioning and combining fractions, though some students required additional support.
   - **Integers**: The activity encouraged students to explore operations with positive and negative numbers, though initial results indicated room for improvement.

2. **Student Engagement and Response**:

   The IDD fostered increased student engagement. Students collaborated actively, supporting one another to solve problems. However, while some misconceptions were addressed, challenges persisted in fractions and integers.

3. **Pedagogical Relations**:

   Teachers used Anticipated Didactical Pedagogies (ADP) to adapt the design based on student responses. This iterative process, as recommended by Simon et al. (2018), allowed for a dynamic adjustment of instructional materials.

Revised Didactical Design

The **Revised Didactical Design (RDD)** refined the initial approach by incorporating feedback from the IDD. The adjustments addressed specific learning obstacles and optimized the integration of the endog-endogan game into the curriculum.

1. **Key Improvements**:

    - **Fractions**: Visual aids, such as diagrams and manipulatives, were introduced to clarify the concept of common denominators. These tools helped students correctly solve problems like $\frac{2}{4} + \frac{3}{4} = \frac{5}{4}$.

    - **Integers**: The game was modified to differentiate positive and negative values, enabling students to grasp operations like −13+5=−8 more effectively.

    - **Subtraction**: The revised design maintained the effectiveness of the game in teaching subtraction, with students demonstrating improved accuracy and confidence.

2. **Student Independence**:

    The RDD fostered greater independence in student learning, a hallmark of didactical situations (Brousseau & Warfield, 2020). By actively engaging with the materials and collaborating with peers, students developed critical thinking skills and a deeper understanding of mathematical concepts.

3. **Cultural Relevance**:

    The integration of Sundanese ethnomathematics through the endog-endogan game highlighted the role of culturally responsive pedagogy. Students found the activities enjoyable and meaningful, reinforcing the value of connecting mathematical learning to their cultural heritage (Mania & Alam, 2021).

Broader Implications

1. **Alignment with Didactical Theory**:

    This study validated the principles of the Theory of Didactical Situations by demonstrating how carefully designed instructional materials can address learning obstacles. The IDD and RDD created environments where students could explore, hypothesize, and formalize mathematical concepts.

2. **Practical Applications**:

- **Teacher Adaptation**: The iterative design process equipped teachers with strategies to anticipate and address learning obstacles effectively.
- **Scalability**: The success of the endog-endogan game suggests its potential applicability in other cultural contexts, provided appropriate adaptations are made.

3. **Challenges and Limitations**:

- Some students required additional support to fully grasp complex concepts like fractions and integers.
- The approach may require further refinement to accommodate larger class sizes or diverse cultural settings.

4. **Future Research**:

Further studies could explore the long-term impact of ethnomathematics-based learning on student achievement and its adaptability to different educational contexts.

Figure 4. Learning Obstacle Stage

Figure 5. Didactic Situation Early Endog-endogan learning

Figure 6. The situation of the Revised Didactic Design of Endog-endogan learning

CONLUSION AND SUGGESTION

Conclusion

The Sundanese ethnomathematics learning materials, developed using the traditional **endog-endogan** game from West Java, Indonesia, have successfully fostered independent learning among students in grades 1 through 6. These materials effectively addressed key mathematical concepts, including addition, subtraction, fractions, and integers.

The integration of the **endog-endogan** game provided a culturally relevant and engaging learning experience, enabling students to connect abstract mathematical concepts with tangible and meaningful activities. Importantly, the game proved to be easily adaptable for all students, regardless of their cultural backgrounds, with no significant barriers observed during implementation.

Student responses to the teaching materials demonstrated alignment with teacher predictions, reflecting the effectiveness of the didactical design. The iterative development process ensured that the materials were optimized to meet students' learning needs, resulting in improved understanding and engagement across all grade levels.

This study highlights the potential of ethnomathematics-based approaches, such as the **endog-endogan** game, to enhance mathematical learning while fostering cultural appreciation and inclusivity. The findings support the broader application of culturally responsive pedagogy in mathematics education, offering a valuable framework for integrating traditional practices into modern teaching methodologies.

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