

A Hybrid Didactical Design through Gendang Beleq Ethnomathematics to Address Students' Learning Obstacles in Understanding Relations and Functions

I Ketut Sukarma¹, Sri Yuliyanti¹, Sutarto¹, Muhamad Galang Isnawan², Intan Dwi Hastuti², Sabrun¹

¹Department of Mathematics Education, Universitas Pendidikan Mandalika, Mataram, Indonesia

²Department of Mathematics Education, Universitas Nahdlatul Wathan Mataram, Indonesia

³Department of Primary School Teacher Education, Universitas Muhammadiyah Mataram, Mataram, Indonesia

HOW TO CITE:

I Ketut Sukarma, Sri Yuliyanti, Sutarto, Muhamad Galang Isnawan, Intan Dwi Hastuti, Sabrun (2026). A Hybrid Didactical Design through Gendang Beleq Ethnomathematics to Address Students' Learning Obstacles in Understanding Relations and Functions International Journal of Special Education, 41(22s),82-100

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ABSTRACT

Understanding relations and functions remains challenging for many junior secondary students due to difficulties in distinguishing relations from functions, identifying domains and ranges, and coordinating multiple mathematical representations. This study aims to develop a hybrid didactical design through Gendang Beleq ethnomathematics to address students' learning obstacles in understanding relations and functions.

This study employed Didactical Design Research (DDR) integrated with the Theory of Didactical Situations (TDS). The research involved eighth-grade students from junior secondary schools on Lombok Island, Indonesia, through iterative phases of a priori analysis, didactical design and anticipation, didactical experimentation, and retrospective analysis. Gendang Beleq was utilized as a culturally meaningful learning resource by transforming rhythmic patterns and musical relationships into mathematical representations, including ordered pairs, mappings, domain-range relationships, and graphs.

Data were collected through diagnostic tests, observations, interviews, students' written work, and teacher reflections. The findings are expected to produce a learning obstacle map, a hypothetical learning trajectory, and a validated Gendang Beleq-based instructional design. This study contributes to inclusive mathematics education by demonstrating how culturally responsive didactical designs can support students experiencing conceptual and representational difficulties in mathematics learning.

Keywords: Hybrid Didactical Design; Didactical Design Research; Ethnomathematics; Gendang Beleq; Mathematics Learning Obstacles

Introduction

Relations and functions are fundamental concepts in junior secondary mathematics because they provide the conceptual foundation for subsequent learning, including linear functions, systems of equations, algebraic modelling, and calculus. Understanding relations and functions requires students not only to perform symbolic procedures but also to recognize correspondences, identify domains and ranges, distinguish relations from functions, and coordinate verbal, tabular, graphical, and symbolic representations. However, students often experience substantial learning obstacles in learning function concepts. These difficulties are associated with distinguishing relations from functions, determining domains and ranges, and coordinating mathematical representations (Firda et al., 2024). Students' misconceptions also occur when interpreting the meaning and representations of functions (Trujillo et al., 2023).

Observations conducted in several junior secondary schools revealed that eighth-grade students encountered difficulties in understanding relations and functions. Based on preliminary diagnostic tests administered in three junior secondary schools in Mataram, Indonesia, 31.2% of students experienced difficulties in distinguishing relations from functions, understanding domains and ranges, and interpreting mathematical representations. These obstacles are significant because fragmented conceptual understanding at this stage may constrain students' mathematical reasoning in subsequent learning. Related studies also emphasize that limitations in mathematical representations, conceptual interpretation, and problem-solving abilities can substantially influence students' learning performance (Maulina et al., 2024; Sridana et al., 2025).

One fundamental difficulty is that relations and functions are commonly introduced through abstract definitions and symbolic forms before students develop sufficient meaningful experiences. Consequently, students are required to coordinate formal mathematical representations without having sufficiently

strong conceptual foundations. Recent research emphasizes that representational flexibility is essential for conceptual understanding, particularly when students move among algebraic, graphical, tabular, and contextual representations (Acharya et al., 2021). Technology-supported environments, such as mathematical software, can facilitate visualization and symbolic reasoning, while contextual and manipulative approaches can provide alternative pathways for students experiencing mathematical difficulties. However, representational support alone may not fully overcome students' difficulties. Learning obstacles need to be examined in relation to how students interpret mathematical situations, how prior knowledge constrains new conceptualization, and how instructional structures shape these interpretations (Jatmiko et al., 2021; Rachma & Rosjanuardi, 2021; Sukarma et al., 2024). Therefore, learning designs should not merely provide additional examples but should systematically respond to diagnosed difficulties and anticipated student reasoning.

Ethnomathematics provides an important foundation for developing meaningful learning situations because it positions cultural experiences as resources for constructing mathematical knowledge. Indigenous and local knowledge can connect students' prior experiences with formal mathematical concepts, enabling abstract mathematics to emerge from familiar and socially meaningful contexts (Pradhan, 2023). Previous studies have demonstrated that ethnomathematics-based learning can enhance the meaningfulness of mathematics by connecting formal concepts with cultural knowledge and students' experiences (Ibrahim & Wahid, 2025; Zainovi et al., 2025). Culturally contextualized mathematics learning has also been associated with stronger engagement, numeracy abilities, mathematical problem-solving, and higher-order thinking when cultural activities are transformed into structured learning experiences rather than merely presented as illustrative examples (Apriatni et al., 2022; Putri et al., 2024; Rahayu, 2025). Recent developments further indicate that ethnomathematics can be

integrated with technology-supported learning pathways and other systematic instructional frameworks, extending its role from cultural documentation toward design-based mathematics education (Nursyahidah et al., 2025; Zulma Elizabete de Freitas Madruga, 2025). In this regard, ethnomathematics provides a cultural and cognitive bridge between students' lived experiences and increasingly formal mathematical reasoning.

Within the Sasak cultural context of Lombok, Gendang Beleq offers a promising ethnomathematical environment. Gendang Beleq represents an important traditional musical practice with ethnopedagogical value and provides culturally meaningful structures through rhythm, temporal sequences, coordinated instrumental patterns, and social performances (Alditia & Nurawanti, 2023). More broadly, Sasak cultural practices contain embedded mathematical relationships that can be interpreted pedagogically (Hastuti et al., 2025). In this study, Gendang Beleq is not positioned merely as a cultural ornament. Its rhythmic and musical structures are translated into mathematical objects relevant to relations and functions: musical instruments and rhythmic patterns serve as contextual objects; beat-time correspondences represent relations; rhythmic sequences support the construction of ordered pairs; and these correspondences can subsequently be represented through graphs, domain-range relationships, and formal functional notation. Such transformation aligns with the broader principle that cultural artifacts can be systematically translated from ethnographic environments into classroom mathematics practices (Pradhan, 2023; Supriadi, 2023). By embedding formal concepts within culturally recognizable structures, Gendang Beleq can provide students with a meaningful pathway from contextual interpretation toward mathematical abstraction.

However, contextualization alone does not guarantee conceptual learning. Effective and culturally responsive instruction requires systematic mechanisms for diagnosing students' learning obstacles, anticipating possible

responses, designing appropriate didactical situations, observing classroom interactions, and revising instructional designs based on empirical evidence. Didactical Design Research (DDR) provides such a framework by connecting the analysis of learning obstacles with instructional development and iterative redesign (Isnawan et al., 2023; Sidik et al., 2023). Previous research has shown that hybrid didactical designs can organize mathematical situations around diagnosed difficulties and provide various forms of support to address learning obstacles (Sukarma et al., 2024). Similarly, contextual didactical resources have been used to strengthen mathematical problem-solving and formal conceptual development (Isnawan et al., 2023; Sukarma et al., 2024). This study further integrates DDR with the Theory of Didactical Situations (TDS), in which learning is organized through action, formulation, validation, and institutionalization situations. This integration enables culturally meaningful tasks to be systematically connected with students' mathematical activities, anticipated responses, and teacher interventions rather than being introduced separately from the underlying learning trajectory (Bartzia et al., 2023).

The proposed framework is conceptualized as a hybrid didactical design because it intentionally integrates cultural contexts, formal mathematics, didactical theories, classroom practices, and technology-supported learning resources. In this study, hybridization does not merely refer to combining face-to-face and digital instruction. Instead, it refers to the intentional coordination of various pedagogical resources capable of responding to different forms of learning obstacles. Existing research indicates that technology-supported and culturally responsive learning can strengthen representational reasoning and provide support for conceptual development when integrated within coherent learning trajectories (Nursyahidah et al., 2025). Likewise, hybrid didactical approaches can accommodate students' difficulties through additional problem contexts, instructional support, and adaptive learning situations while maintaining didactical rigor (Sridana et al., 2025). Such integration is particularly relevant for

relations and functions because students need to move flexibly among contextual situations, ordered pairs, graphs, domain–range structures, and symbolic representations. Therefore, the proposed hybrid design aims to create interconnected learning pathways through which students can construct formal mathematical meaning from culturally situated experiences.

Although international attention to ethnomathematics has increased over the past two decades, important gaps remain. Existing literature has predominantly focused on identifying mathematical ideas embedded in cultural practices, developing culturally contextualized materials, or investigating arithmetic and geometry topics (Arisetyawan et al., 2025; Kho et al., 2025; Mellawaty et al., 2025). Although these studies demonstrate the educational potential of local cultural knowledge, research integrating ethnomathematics with rigorous design-oriented frameworks for algebraic concepts remains limited. Specifically, studies that simultaneously integrate DDR, TDS, ethnomathematics, and hybrid learning to address learning obstacles in relations and functions remain scarce. Research utilizing Sasak cultural artifacts, particularly Gendang Beleq, as structural sources for mathematical tasks involving domain–range reasoning, ordered pairs, and function graphs is also limited. Existing ethnomathematics-DDR studies have mainly emphasized arithmetic and geometry rather than intermediate functional reasoning. Consequently, a methodological and conceptual gap remains between cultural contextualization, diagnosis of learning obstacles, didactical anticipation, classroom implementation, and iterative instructional redesign.

This study addresses this gap by developing a culturally responsive hybrid didactical design that integrates Gendang Beleq ethnomathematics, DDR, and TDS for learning relations and functions among eighth-grade students. The novelty of this study lies in transforming Gendang Beleq's musical structures into mathematically organized learning situations that

directly connect diagnosed learning obstacles with hypothetical learning trajectories, anticipated student responses, classroom implementation, and retrospective refinement. The study is guided by the following research questions:

How can a hybrid didactical design based on Gendang Beleq ethnomathematics address students' learning obstacles in understanding relations and functions, particularly epistemological and representational obstacles?

How can the implementation of a Gendang Beleq-based hybrid didactical design strengthen students' conceptual understanding while reducing learning obstacles in relations and functions?

This study assumes that culturally meaningful mathematical situations can provide conceptual foundations that support students' transition from contextual reasoning to formal mathematics more effectively than abstract symbolic instruction alone. Therefore, the expected contribution extends beyond the development of instructional modules; rather, this study seeks to generate empirically grounded design principles explaining how cultural structures, learning obstacles, didactical anticipation, student responses, and iterative instructional refinement can be systematically connected within culturally responsive mathematics education.

2. Methodology

This study employed a Didactical Design Research (DDR) approach conducted through four iterative phases: (1) a priori analysis, (2) didactical design and anticipation, (3) didactical experiment, and (4) retrospective analysis. The primary objective of this approach was to develop an effective didactical design for addressing students' learning obstacles by focusing on the analysis of interactions among students, learning tasks, and instructional contexts. This approach is iterative in nature, enabling continuous evaluation and refinement of the design based on findings obtained from each research cycle.

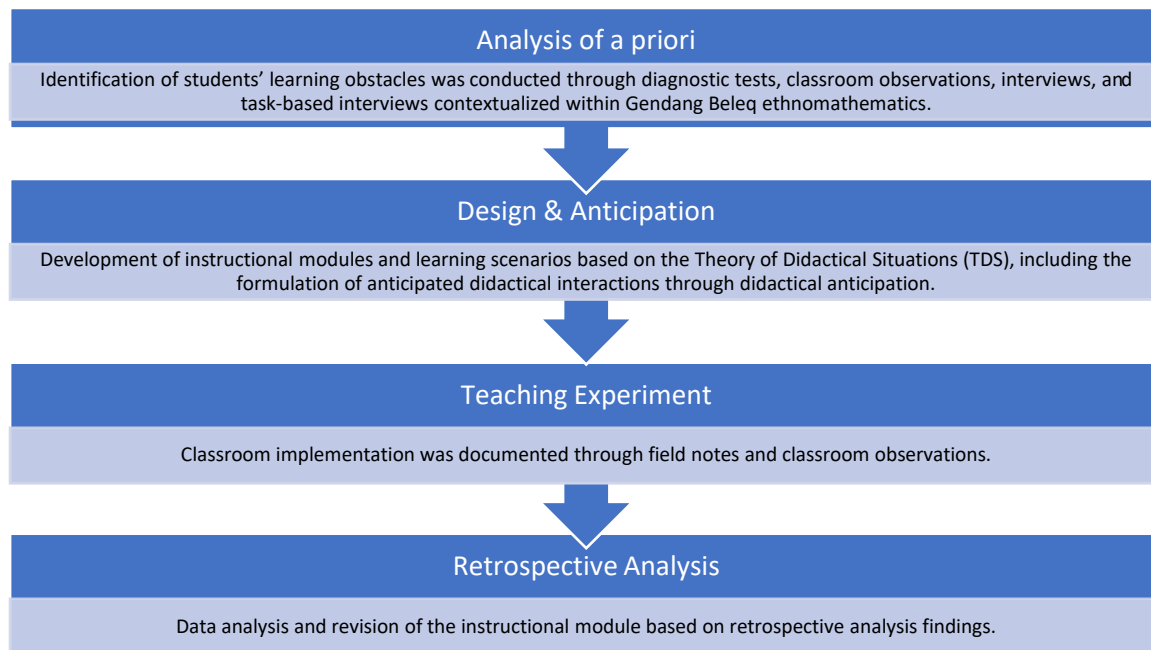


Figure 1. The Stages of the Didactical Design Research (DDR) Process

A Priori Analysis

The first phase aimed to identify students' learning obstacles, particularly related to function concepts, before designing the instructional intervention. At this stage, several methods were employed to identify and analyze students' learning obstacles: (1) concept-based diagnostic tests, (2) classroom observations, (3) clinical interviews with students and teachers at SMPN 11 Mataram, and (4) task-based interviews using the Gendang Beleq context.

The concept-based diagnostic test was designed to identify students' prior understanding and difficulties in distinguishing relations from functions, identifying domains, codomains, and ranges, interpreting ordered pairs, and coordinating multiple mathematical representations. Diagnostic tests have been widely used in DDR-oriented studies to identify conceptual, epistemological, and representational learning obstacles prior to didactical intervention.

Classroom observations were conducted to document how students responded to existing teaching practices and to identify learning difficulties emerging during classroom interactions. Observation data complemented the diagnostic tests by providing contextual evidence

regarding instructional conditions in which specific learning obstacles occurred.

Clinical interviews with students were conducted to investigate the reasoning underlying students' written responses, including how they interpreted function concepts, selected solution strategies, and justified their mathematical reasoning. Clinical interviews with teachers were conducted to obtain complementary information regarding recurring classroom difficulties, instructional practices, and teachers' interpretations of students' responses.

Task-based interviews introduced mathematical problems contextualized through Gendang Beleq ethnomathematics. These interviews were designed to investigate how students interpreted relations and functions within the context of Gendang Beleq, particularly the relationship between musical instruments and the sounds they produced.

Evidence obtained from these four methods was integrated to construct a comprehensive Learning Obstacle Map. This map was intended not only to describe whether students were able to solve mathematical problems but also to reveal patterns of reasoning, representations, misconceptions, and learning conditions

associated with epistemological, didactical, and ontogenetic obstacles.

The diagnostic evidence subsequently became the foundation for developing the initial Hypothetical Learning Trajectory (HLT). This study also incorporated the Theory of Didactical Situations (TDS) to organize learning activities into action, formulation, validation, and institutionalization situations. These stages were integrated into the HLT framework to anticipate and analyze interactions among students, learning tasks, and teachers.

Therefore, the expected outcomes of this phase were a comprehensive map of students' learning obstacles and an initial learning trajectory that informed the subsequent pre-didactical design.

Didactical Design and Anticipation

In this phase, the learning sequence was designed through four didactical situations: action, formulation, validation, and institutionalization. In the action situation, students interacted with contextual mathematical problems related to Gendang Beleg and developed their initial strategies. During the formulation situation, students communicated and represented mathematical relationships emerging from the Gendang Beleg context. The validation situation

required students to justify and evaluate their reasoning, while the institutionalization situation supported the transition from contextual constructions toward formally accepted concepts of relations and functions.

The mathematical transformation began by treating Gendang Beleg musical instruments, temporal counts, and the number of beats as contextual mathematical objects. The correspondence between time sequences and the number of beats was interpreted as a relation, while rhythmic patterns were represented through ordered pairs, mappings, domain–range relationships, and graphical representations. This structure was designed to support students' development from culturally contextualized reasoning toward increasingly formal mathematical representations.

A key component of this phase was didactical anticipation. Before classroom implementation, researchers predicted possible student responses, appropriate strategies, misconceptions, representational difficulties, and potential learning obstacles. For each anticipated response, possible teacher interventions were prepared to support students' conceptual development and address emerging learning obstacles.

Table 1. Learning Conjectures for Teaching Relations and Functions through Gendang Beleg Ethnomathematics

Stages	Activity Description	Learning Conjectures
Action Situation	Activity 1: Exploring types of musical instruments and sounds produced in Gendang Beleg performances and identifying mathematical relationships through cultural experiences. Description: Students observe and explore the structure of Gendang Beleg performances, including the roles of musical instruments (gendang, gong, ceng-ceng, and rincik), the sounds produced, time sequences, and the number of beats. Students are presented with contextual situations related to the types of Gendang Beleg instruments, the sounds produced, time sequences, and the number of	1. Students begin to recognize that Gendang Beleg contains patterns and relationships that can be represented mathematically. 2. Students are able to identify initial relationships between types of Gendang Beleg instruments and the sounds produced, time sequences, and the number of beats; however, they may not yet clearly distinguish between relations and functions. 3. Students begin to develop an intuitive understanding that each musical event can be associated

	beats. Students work with cultural representations, including types of musical instruments in Gendang Beleg performances, the sounds produced, time sequences, and the number of beats, to identify relationships among musical elements.	with other elements through particular relationships. 4. Students may still experience difficulties in determining which elements represent input values and output values within the cultural context.
Formulation Situation	Activity 2: Constructing mathematical representations of Gendang Beleg patterns. Description: Students formulate mathematical representations based on relationships identified within Gendang Beleg patterns. Students construct ordered pairs representing relationships among musical components, such as relationships between types of instruments and sounds produced, time sequences and the number of beats, rhythmic patterns and duration, or instrumental patterns and sound sequences. Students represent these relationships in tables and discuss possible representations using arrow diagrams or mapping models. Through group discussions, students formulate mathematical statements based on relationships identified from the cultural context.	1. Students are able to translate cultural observations into mathematical models using ordered pairs, tables, and mapping diagrams. 2. Students begin to understand that a relation represents a relationship between two sets, for example, the relationship between beat numbers and time intervals. 3. Students may still experience difficulties in determining domains and ranges, particularly in identifying input and output variables. 4. Students begin to develop criteria for determining whether a relationship within Gendang Beleg represents a function or merely a relation. 5. Students are able to explain mathematical ideas through cultural narratives related to rhythmic patterns and musical performances.
Validation Situation	Activity 3: Testing and validating functional relationships through Gendang Beleg mathematical models. Description: Students analyze various relationship models based on Gendang Beleg and determine whether these relationships satisfy the concept of a function. Students validate their reasoning by comparing domains, ranges, ordered pairs, and mapping diagrams. Students discuss examples such as:	1. Students are able to validate whether relationships based on Gendang Beleg satisfy the definition of a function. 2. Students understand that each element in the domain must have exactly one corresponding element in the range for a relationship to be classified as a function. 3. Students improve their ability to transition among mathematical representations, including cultural

	- One rhythmic pattern corresponds to one specific duration value (function). - One instrumental pattern produces several different outputs (not necessarily a function). Students provide mathematical justifications through discussions and peer arguments.	descriptions, ordered pairs, tables, arrow diagrams, and graphs. 4. Students may still experience difficulties in understanding graphical representations of functions. 5. Students develop mathematical reasoning skills by explaining why a relationship represents a function or does not represent a function.
Institutionalization Situation	Activity 4: Formalizing relations and functions concepts from the Gendang Beleg context. Description: Students and teachers construct formal mathematical concepts based on previous activities. Teachers guide students in generalizing mathematical ideas obtained from the Gendang Beleg context into formal definitions of relations and functions. Students construct final representations in the forms of: - sets (domain and range), - ordered pairs, - arrow diagrams, - tables, - Cartesian graphs. Students solve contextual problems related to Gendang Beleg patterns and explain the relationship between cultural phenomena and mathematical concepts.	1. Students are able to construct formal definitions of relations and functions based on previous cultural exploration experiences. 2. Students demonstrate conceptual understanding that a function is a special type of relation in which each element of the domain has exactly one corresponding element in the range. 3. Students are able to connect Gendang Beleg cultural structures with formal mathematical representations. 4. Students experience cognitive development from context-based reasoning toward abstract mathematical reasoning. 5. Students are able to apply relations and functions concepts to new mathematical problems beyond the Gendang Beleg context.

Didactical Experiment

This study adopted a design experiment approach consisting of two cycles to develop, implement, and refine a learning trajectory for relations and functions based on the local cultural context of Gendang Beleg. The purpose of this experiment was to guide students from informal cultural experiences toward formal mathematical understanding through kinesthetic-based learning activities.

Cycle 1 – Initial Implementation

The first cycle was conducted with a small group of 25 students from SMP Negeri 11 Mataram. Students were categorized into three groups based on their initial mathematical abilities: high, medium, and low ability levels. This classification aimed to capture students' learning responses across different levels of mathematical ability. During this cycle, the initial Hypothetical Learning Trajectory (HLT) was implemented through three learning stages. Based on insights and challenges identified during Cycle 1, several revisions were made to improve the HLT.

Cycle 2 – Implementation of the Revised HLT

The second cycle was conducted in a different classroom within the same school, involving 28 students with similar variations in mathematical ability. The revised HLT was reimplemented through the same three instructional stages. Data were collected throughout both cycles using video recordings, field notes, photographic documentation, students' worksheets, observation sheets, student feedback forms, and post-activity interviews.

These instruments captured students' learning processes, levels of engagement, and challenges, particularly their difficulties in applying movement patterns and transitioning from kinesthetic experiences to symbolic representations. The collected data were systematically analyzed to identify patterns of misconceptions and areas requiring further support. Insights from this analysis directly informed revisions to the Hypothetical Learning Trajectory (HLT), leading to clearer movement instructions, improved role distribution, enhanced learning materials, and better integration of cultural elements.

Therefore, the didactical experiment generated multiple complementary forms of evidence rather than relying on a single performance indicator. Video recordings, students' written work, observation notes, and teacher reflections collectively provided empirical foundations for evaluating how the designed learning situations functioned in practice. The expected outcomes of this phase were comprehensive documentation of student-teacher interactions, student responses, students' mathematical written work, implementation observations, and teachers' reflective feedback.

Retrospective Analysis

The final phase evaluated the implemented learning design through retrospective analysis. This phase compared the anticipated learning trajectory with actual classroom events to determine the extent to which predicted student responses occurred and to identify unexpected

reasoning, misconceptions, representational difficulties, and remaining learning obstacles.

All data obtained during the didactical experiment phase were analyzed by comparing the initial assumptions and HLT developed during the preliminary design phase with the actual outcomes of the implemented learning trajectory. This analysis aimed to evaluate the alignment between the designed learning trajectory and students' responses during the learning process, as well as to understand how students constructed their understanding of relations and functions through a culturally contextualized approach.

The analysis involved comparing classroom observations, field notes, and video recordings with the initial hypotheses developed during the preliminary design phase. Data were analyzed using a comparative approach by aligning observed student behaviors and learning outcomes with the expectations outlined in the HLT. This iterative process ensured that the developed learning trajectory was not only pedagogically effective but also culturally relevant.

3. Results

3.1 Identification of Students' Learning Obstacles (A Priori Analysis)

The a priori analysis was conducted to identify students' learning obstacles in understanding relations and functions before the instructional intervention was designed. Data were collected through concept-based diagnostic tests, interviews with students and teachers at SMPN 11 Mataram, and classroom observations.

The concept-based diagnostic test examined students' initial understanding of relations and functions, including domains, codomains, ranges, and ordered pairs. The results revealed three main learning obstacles experienced by students: (1) difficulties in distinguishing relations from functions, (2) difficulties in interpreting ordered pairs, and (3) difficulties in determining whether a given representation represented a function.

Student interviews were conducted to further investigate the reasoning underlying students' responses. The interviews showed that students' difficulties were related not only to incorrect answers but also to incomplete conceptual understanding.

For example, when students were asked why a relationship represented a function, one student responded:

"Because the arrows look organized, I think it is a function."

This response indicated that the student relied on visual characteristics rather than the mathematical criterion that each element in the domain must have exactly one corresponding element in the range.

Another student demonstrated difficulty in interpreting ordered pairs:

"I am not sure, sometimes the first number is the output."

This response indicated uncertainty regarding the role of input and output components in ordered pairs.

Teacher interviews provided additional evidence that students often relied on procedural steps and memorized formulas without fully understanding the conceptual meaning of relations and functions. Classroom observations also showed that mathematics instruction was predominantly procedural and textbook-oriented, with limited integration of meaningful cultural contexts.

Based on these findings, Gendang Beleg was incorporated as a contextual learning resource. The relationship between musical instruments and sounds produced was used as an initial representation of mathematical relations.

Together with mathematics teachers, the researchers developed an initial Hypothetical Learning Trajectory (HLT) as a flexible framework that allowed refinement based on classroom implementation and students' responses.

Table 1. Identified Learning Obstacles in Understanding Relations and Functions

Learning Obstacles	Evidence of Students' Difficulties
Distinguishing relations and functions	Students experienced difficulties identifying characteristics that differentiate relations from functions.
Interpreting ordered pairs	Students experienced difficulties determining input and output components within mathematical relationships.
Identifying function representations	Students relied on visual patterns rather than mathematical criteria when determining whether a relationship represented a function.

3.2 Development of the Hybrid Didactical Design

Based on the identified learning obstacles, a hybrid didactical design was developed by integrating Gendang Beleg ethnomathematics, Didactical Design Research (DDR), and the Theory of Didactical Situations (TDS).

The learning trajectory consisted of four didactical situations: action, formulation, validation, and institutionalization.

In the action situation, students explored Gendang Beleg instruments, sounds produced, rhythmic patterns, time sequences, and beat patterns to identify mathematical relationships through cultural experiences.

In the formulation situation, students constructed mathematical representations of Gendang Beleg patterns using ordered pairs, tables, and mapping diagrams. Students represented relationships among musical components, including relationships between

instruments and sounds, time sequences and the number of beats, rhythmic patterns and duration.

In the validation situation, students examined mathematical relationships derived from Gendang Beleq patterns and determined whether these relationships fulfilled the characteristics of functions.

In the institutionalization situation, students formalized relations and functions concepts through multiple mathematical representations, including sets, ordered pairs, mapping diagrams, tables, and Cartesian graphs.

3.3 Implementation of the Didactical Experiment

The didactical experiment was conducted through two iterative cycles. The learning trajectory guided students from informal cultural experiences toward formal mathematical understanding through four sequential activities: action, formulation, validation, and institutionalization.

3.3.1 Action Situation: Exploring Gendang Beleq Instruments and Sounds

Students began the learning process by exploring Gendang Beleq as a cultural context for understanding relations. Students observed a Gendang Beleq performance video and identified various musical instruments and sound patterns produced.

The classroom dialogue demonstrated students' initial recognition of relationships embedded within the cultural context.

Teacher: "Before we begin learning about relations, has anyone ever seen a Gendang Beleq performance?"

Student 1: "Yes, Ma'am. I have seen it during a traditional ceremony."

Teacher: "If you observe the performance carefully, is there only one musical instrument used in Gendang Beleq?"

Student 2: "No, Ma'am. There are several musical instruments."

Teacher: "What musical instruments did you observe in the video?"

Student 3: "There are gendang, gong, and ceng-ceng, Ma'am."

Student 4: "There is also rincik, Ma'am."

Teacher: "Do all musical instruments produce the same sound?"

Student 1: "No, Ma'am. The sound of the gendang is different from the gong."

Teacher: "Can we establish a relationship between a particular musical instrument and the sound it produces?"

Student 3: "Yes, Ma'am. Gendang is related to the sound of gendang, gong is related to the sound of gong, and ceng-ceng is related to the sound of ceng-ceng."

The dialogue shows that students began identifying correspondence between two cultural sets: musical instruments and sounds produced.

Students then worked collaboratively using worksheets to explore relationships within the Gendang Beleq context. Students constructed two sets from cultural elements, determined relationships between members of the sets, represented these relationships using tables and arrow diagrams, and expressed them through ordered pairs.

3.3.2 Formulation Situation: Constructing Mathematical Representations of Gendang Beleq Patterns

Students analyzed rhythmic patterns, time sequences, and the number of beats in Gendang Beleq performances. The cultural context was transformed into a mathematical relationship between two quantities: time and the number of beats.

The classroom dialogue illustrates students' transition from recognizing cultural patterns toward constructing mathematical relationships.

Teacher: "What relationship is shown in this table?"

Student 1: "The time count is related to the number of beats, Ma'am."

Teacher: "How are they related?"

Student 2: "When the time increases, the number of beats also increases, Ma'am."

Teacher: "When the time count is 1, how many beats are produced?"

Students: "Two beats."

Teacher: "When the time count is 2?"

Students: "Four beats."

Teacher: "When the time count is 3?"

Students: "Six beats."

Teacher: "Does each time count have a corresponding number of beats?"

Students: "Yes, Ma'am."

The dialogue indicates that students began recognizing correspondence between two quantities and representing these relationships mathematically.

3.3.3 Validation Situation: Testing and Validating Functional Relationships through Gendang Beleg Mathematical Models

In this stage, students examined and validated functional relationships through mathematical models derived from Gendang Beleg patterns. Students analyzed rhythmic patterns, time sequences, and the number of beats to determine whether the identified relationships fulfilled the characteristics of functions.

During the problem orientation stage, students observed tables showing the relationship between time sequences and the number of beats. Students were guided to identify patterns, predict subsequent values, and formulate mathematical rules based on the observed relationships.

The following classroom dialogue illustrates students' reasoning processes during the validation situation.

Teacher: "Students, in the previous meeting we learned about relations and functions. Who can still remember what a function means?"

Student 1: "A function is a special relation, Ma'am."

Teacher: "Good. What does a special relation mean?"

Student 1: "Each element in the domain has exactly one corresponding element in the codomain."

Teacher: "Excellent. Can the concept of functions only be found in mathematics problems?"

Student 2: "No, Ma'am. It can also be found in everyday life."

Teacher: "That is correct. Today, we will explore how functions can be found in cultural activities, particularly in Gendang Beleg."

The teacher then presented a rhythmic pattern table based on Gendang Beleg performances.

Teacher: "Look at this data. How many beats are produced in the first minute?"

Students: "Three beats."

Teacher: "What about the second minute?"

Students: "Six beats."

Teacher: "The third minute?"

Students: "Nine beats."

Teacher: "The fourth minute?"

Students: "Twelve beats."

Teacher: "Do you notice any pattern?"

Student 3: "Yes, Ma'am. The number of beats increases."

Teacher: "How much does it increase each minute?"

Student 3: "Three beats."

Teacher: "If the pattern continues, how many beats will be produced in the fifth minute?"

Student 4: "Fifteen beats."

Teacher: "How did you obtain fifteen?"

Student 4: "Because twelve is added by three."

Teacher: "If I ask about the tenth minute, how many beats will be produced?"

Student 1: "Thirty beats."

Teacher: "Why?"

Student 1: "Because each minute is multiplied by three."

Teacher: "Can we only determine the number of beats from the table, or can we find a rule that applies to all time intervals?"

Student 2: "We can find the rule, Ma'am."

The dialogue shows that students began identifying patterns, predicting values, and generalizing relationships from Gendang Beleg rhythmic sequences.

During the investigation stage, students worked collaboratively using worksheets. The activities required students to identify relationship patterns from beat data and use these patterns to determine unknown values.

Students were also guided to compare examples and non-examples of functions by examining whether each element in the domain had exactly one corresponding element in the codomain.

During the presentation stage, each group presented their findings, while other groups provided responses and feedback. The teacher and students then formulated conclusions regarding the characteristics of functions based on the investigated relationships.

3.3.4 Institutionalization Situation: Formalizing Relations and Functions Concepts through the Gendang Beleg Context

Based on the exploration and validation activities, students formalized relations and functions concepts from the Gendang Beleg context.

Students identified regularities in the relationship between time sequences and the number of beats and generalized these relationships into function rules. During discussions, students interpreted the variables representing time sequences as inputs and the number of beats as outputs.

Students were also able to explain that each element in the domain must have exactly one corresponding element in the codomain, indicating the characteristics of a function.

The institutionalization process showed that students began coordinating multiple mathematical representations. Relationships derived from the Gendang Beleg context were represented through:

sets, ordered pairs, mapping diagrams, tables, Cartesian graphs.

For example, students represented the relationship between the fourth time count and twelve beats as an ordered pair, a mapping relationship, and a coordinate point on a Cartesian graph.

Furthermore, students were given new contextual problems requiring them to apply function rules obtained from previous activities. Students used the established relationships to determine unknown values and interpret the results within the Gendang Beleg context.

3.4 Retrospective Analysis and Design Refinement

The retrospective analysis was conducted after the didactical experiment phase to compare the anticipated learning trajectory with students' actual responses during implementation. Data were obtained through video recordings, field notes, photographic documentation, students' worksheets, and students' written responses.

The analysis was organized based on four learning trajectory stages: action, formulation, validation, and institutionalization.

In the action situation, several students were able to recognize relationships within the Gendang Beleg context and connect them with mathematical relations. However, some students remained focused on cultural observations and had difficulty transforming cultural objects into mathematical relationships.

Based on this finding, the HLT was revised in Cycle 2 by adding guiding questions that directed students from cultural objects toward mathematical elements.

In the formulation situation, students were able to identify relationships between time sequences and the number of beats; however, some students

still relied on teacher guidance when expressing these relationships mathematically.

Therefore, in Cycle 2, didactical questions were refined gradually through questions such as:

“What information is known?”

“What elements are related?”

“Which elements represent input and output?”

“How can this relationship be represented mathematically?”

These revisions provided students with greater opportunities to formulate mathematical relationships using their own reasoning before formal notation was introduced.

In the validation situation, refinement of the HLT focused on strengthening examples and non-examples of functions. Students in Cycle 2 were provided with both relationships that represented functions and relationships that did not represent functions.

Students compared these relationships and justified their decisions based on the number of corresponding elements associated with each domain element.

In the institutionalization situation, students were provided with greater opportunities to construct generalizations before formal definitions were introduced. Students explained patterns they discovered, compared results among groups, and formulated formal concepts of relations and functions together with the teacher.

3.5 Students' Conceptual Development

Students' responses toward the learning experience were collected through questionnaires. The results showed that 92.86% of the 28 participating students provided positive responses, while 7.14% expressed neutral responses.

The students' conceptual development across learning activities is presented in Table 2.

Learning Activity	Evidence of Students' Understanding	Percentage
Exploring relations through Gendang Beleg context	Students identified relationships between musical instruments and sounds produced	89.3%
Constructing mathematical models	Students represented cultural relationships using mathematical representations	85.7%
Solving formal mathematical problems	Students solved problems using mapping diagrams and explained their reasoning	82.1%

The results showed that students' achievement gradually decreased as the complexity of mathematical activities increased. The percentage decreased from 89.3% in contextual exploration activities to 85.7% in mathematical modeling activities and 82.1% in formal mathematical problem-solving activities.

4. Discussion

4.1 Gendang Beleg Ethnomathematics as a Bridge for Addressing Students' Learning Obstacles

The findings demonstrate that Gendang Beleg ethnomathematics provided a meaningful contextual foundation for students to construct understanding of relations and functions. The learning process enabled students to begin with familiar cultural experiences before gradually transitioning toward formal mathematical concepts. Rather than presenting relations and

functions through abstract definitions and symbolic procedures alone, the learning design positioned cultural practices as meaningful mathematical resources.

The use of Gendang Beleg allowed students to recognize mathematical relationships embedded within cultural elements, particularly the correspondence between musical instruments and sounds, as well as between time sequences and the number of beats. These contextual relationships supported students in developing initial mathematical structures before formal representations were introduced.

This finding is consistent with previous ethnomathematics studies emphasizing that cultural contexts can serve as cognitive bridges between students' lived experiences and formal mathematical knowledge. Cultural practices provide accessible conceptual frameworks that enable students to construct meaning from mathematical ideas through familiar situations (Umbara et al., 2021). Furthermore, ethnomathematics research highlights that informal cultural representations can support students' transition toward institutionalized mathematical knowledge (Prahmana et al., 2023).

The present study extends this perspective by demonstrating that Gendang Beleg was not merely used as a cultural illustration but functioned as a structural source for designing mathematical tasks. Musical patterns, beat sequences, and sound relationships were transformed into mathematical objects involving relations, functions, ordered pairs, domain-range structures, and graphical representations.

4.2 The Contribution of Hybrid Didactical Design Research in Developing Conceptual Understanding

The findings indicate that the hybrid didactical design supported students' conceptual development through an iterative process of diagnosis, anticipation, implementation, and refinement. The DDR framework enabled researchers to identify students' learning obstacles before designing instructional

situations and continuously revise the learning trajectory based on students' actual responses.

The retrospective analysis showed that learning obstacles were not treated as fixed deficiencies but as information for improving the design. Difficulties experienced by students during the action, formulation, validation, and institutionalization situations became the basis for revising the Hypothetical Learning Trajectory (HLT), improving teacher interventions, and refining didactical questions.

This finding supports the fundamental principle of Didactical Design Research, which emphasizes that effective learning designs should be developed based on students' actual reasoning processes and conceptual difficulties rather than relying solely on predetermined instructional sequences. Iterative design processes allow researchers and teachers to identify which components of instructional tasks require modification and refinement (Prediger et al., 2021).

The integration of the Theory of Didactical Situations (TDS) also contributed to students' gradual movement from contextual understanding toward formal mathematical reasoning. Through action, formulation, validation, and institutionalization situations, students were provided opportunities to construct, communicate, validate, and formalize mathematical ideas.

4.3 Supporting Inclusive Mathematics Education through Culturally Responsive Design

This study contributes to inclusive mathematics education by demonstrating how culturally responsive hybrid didactical designs can support students experiencing conceptual and representational learning obstacles.

The identified obstacles in this study were not only related to students' final answers but also reflected difficulties in interpreting mathematical representations, connecting input-output relationships, and coordinating multiple forms of representation. Therefore, providing alternative pathways through cultural contexts and multiple

representations became essential for supporting students' mathematical understanding.

The use of Gendang Beleq enabled students to access abstract mathematical concepts through various representations, including cultural descriptions, tables, ordered pairs, mapping diagrams, and Cartesian graphs. These multiple pathways allowed students to gradually construct meaning rather than immediately engage with abstract symbolic forms.

From an inclusive education perspective, this finding suggests that mathematics instruction should consider students' diverse reasoning processes and learning barriers. A culturally responsive approach may provide more accessible learning environments by connecting mathematical concepts with students' prior knowledge, experiences, and cultural backgrounds.

4.4 Theoretical and Practical Implications

Theoretically, this study contributes to the intersection between ethnomathematics and Didactical Design Research by demonstrating that cultural contexts can function not only as sources of mathematical examples but also as foundations for systematic instructional design.

Previous ethnomathematics studies have frequently emphasized identifying mathematical ideas embedded within cultural practices. This study extends that perspective by showing how cultural structures can be transformed into a complete learning trajectory involving diagnosis of learning obstacles, didactical anticipation, classroom implementation, and retrospective refinement.

The findings also contribute to the understanding of how local cultural practices can support the development of mathematical representations. In the context of relations and functions, students' movement among cultural experiences, ordered pairs, mapping diagrams, tables, and graphs illustrates the importance of connecting informal and formal mathematical reasoning.

Practically, this study provides implications for mathematics teachers. Teachers may utilize local

cultural resources as meaningful contexts for developing mathematical understanding, particularly when students experience difficulties with abstract concepts. The developed hybrid didactical design can serve as a reference for designing culturally responsive mathematics learning activities.

4.5 Limitations and Future Research

This study has several limitations that should be considered when interpreting the findings. First, the implementation was conducted in one school context and focused specifically on Gendang Beleq ethnomathematics. Therefore, the transferability of the findings to other cultural settings or geographical contexts requires further investigation.

Second, the number of participants was relatively limited. Although the qualitative design provided detailed insights into students' reasoning processes and learning obstacles, broader studies involving larger participants are needed to examine the applicability of the developed design across different learning contexts.

Third, this study primarily employed qualitative evidence. Future research may incorporate quantitative or mixed-method approaches to provide additional evidence regarding students' conceptual development and the broader implementation of hybrid didactical designs.

Future studies may also explore the integration of other local cultural practices into mathematics learning and investigate how teachers can be supported through professional development programs to sustainably implement ethnomathematics-based learning designs in formal education.

5. Conclusion

This study demonstrates that students' understanding of relations and functions can be developed through the integration of local cultural contexts, particularly Gendang Beleq ethnomathematics. The study developed and implemented a hybrid didactical design that utilized Gendang Beleq, a traditional musical performance originating from Lombok, West

Nusa Tenggara, Indonesia, as a meaningful context for learning mathematical concepts. Gendang Beleg, which is performed collectively by groups of musicians with the large drum (gendang beleg) as the central instrument, provided a cultural foundation for connecting students' experiences with formal mathematical reasoning.

The developed learning trajectory consisted of four sequential didactical activities. In the first activity, students explored Gendang Beleg musical instruments and sounds produced to identify mathematical relationships through cultural experiences. In the second activity, students constructed mathematical representations of Gendang Beleg patterns by analyzing sound regularities, beat patterns, tempo, and coordination among musical instruments. In the third activity, students examined and validated functional relationships through mathematical models derived from Gendang Beleg patterns by identifying regularities, predicting subsequent values, and generalizing mathematical rules. In the fourth activity, students formalized relations and functions concepts by coordinating multiple mathematical representations, including sets, ordered pairs, mapping diagrams, tables, and Cartesian graphs.

The findings indicate that the integration of Gendang Beleg ethnomathematics within a hybrid didactical design provided a structured pathway for students to move from culturally situated experiences toward formal mathematical

understanding. The design also contributed to addressing students' learning obstacles by supporting the development of conceptual understanding and representational flexibility in learning relations and functions.

This study has several limitations. First, the implementation was conducted in a single research site and focused specifically on Gendang Beleg ethnomathematics, which may limit the transferability of the findings to other cultural and geographical contexts. Second, the relatively small number of participants may affect the broader generalizability of the findings. Third, this study primarily employed qualitative methods; although these approaches provided detailed insights into students' reasoning processes and learning obstacles, future research using quantitative or mixed-method approaches is needed to provide more comprehensive evidence regarding the broader applicability of the developed design.

This study contributes to mathematics education research by providing a culturally responsive and replicable hybrid didactical design model that integrates local cultural practices into mathematics learning trajectories. Future research should investigate the application of this approach across diverse cultural contexts, explore its integration within broader curriculum frameworks, and examine teacher professional development strategies to support the sustainable implementation of ethnomathematics-based learning in formal education.

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