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Learning Trajectory on Probability Using the Context of the Bekulo Tradition

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Abstract. In everyday life, individuals are required to be cautious in making decisions and analyzing the possibilities of various alternatives. Probability theory emerges as one of the important branches of mathematics that provides an understanding of uncertainty and ways to measure the likelihood of an event. However, field observations reveal that many students still encounter difficulties in understanding probability, particularly in the subtopic of combinations. These difficulties are generally caused by abstract learning processes, limited contextual activities, and the lack of connection between mathematics and real-life experiences or local culture close to students' lives. This study aims to design probability learning based on Indonesian Realistic Mathematics Education (IRME) by utilizing the Bekulo tradition in Rejang Lebong Regency as a relevant local cultural context. The method employed is design research with a validation study type, involving ninth-grade students of SMP IT Salsabillah Rejang Lebong as research subjects. Data were collected through observation, documentation, and interviews. In this study, the researchers developed a Hypothetical Learning Trajectory (HLT) adapted to the Bekulo tradition context. The results show that integrating IRME with cultural contexts can effectively support the development of students' understanding of the concept of combinations in a more meaningful way. These findings affirm that culturally rooted learning designs not only enrich students' learning experiences but also foster their appreciation of local wisdom while making mathematics more relevant to everyday life.

Keywords: Learning Trajectory; Probability; Bekulo Tradition

1. Introduction

Mathematics is a subject taught from elementary school through higher education. It is not only studied as an abstract discipline but also applied in daily life and closely connected to other fields of knowledge (Aminah, at al., 2018). Moreover, mathematics is regarded as a universal language that underpins the development of science and modern technology (Niss and Blum, 2020).

One of the mathematical topics closely related to real-life situations is probability. Probability deals with measuring the likelihood of an event, encompassing concepts such as chance, risk, reward, and randomness, which frequently arise in everyday activities (Fauzan, et al., 2022; Libka and Adam 2006). Probability is also included as an essential component of the *Merdeka Curriculum*, taught from Phase A to Phase F. At Phase F, students are expected to understand conditional probability, independent events, and apply permutations and combinations. This aligns with the view of Jones, et al.(2007),, who argue that probability is a key concept supporting decision-making skills in real-life contexts. However, many students face difficulties in learning probability, particularly in the subtopic of combinations.

One possible effort to address these difficulties is through meaningful learning design that incorporates real-life contexts relevant to students. The Indonesian Realistic Mathematics Education (IRME) approach emphasizes the importance of using students' everyday contexts so that they can construct their own mathematical knowledge. Recent studies confirm that IRME is effective in improving learning outcomes and mathematical thinking skills. For instance, Pramartha, (2024) reported that implementing IRME improved students' conceptual understanding and learning outcomes in probability. Similarly, Zulkardi, et al., (2020) found that

IRME provides opportunities for students to connect real-world problems with mathematical models, thereby making learning more meaningful.

1.1. Problem Statement

Mathematics learning, particularly in the topic of probability with the subtopic of combinations, remains a significant challenge for high school students. Several studies (Fida, 2025; Rochim, 2022; Triliana & Asih, 2019) have shown that students frequently make errors in understanding concepts, constructing mathematical models, and solving combination problems. The main difficulties lie in distinguishing between permutation and combination problems and inaccuracy during the solution process. Consequently, many students are unable to connect the concept of combinations with real-life contexts, making the learning process abstract and less meaningful.

One of the causes of this issue is the conventional teaching approach often applied by teachers, which provides limited opportunities for students to construct knowledge through contextual experiences. Previous research Anggraini, et al. (2022) and Matitaputty, et al. (2022) has emphasized that meaningful learning design can reduce student errors while increasing motivation and conceptual understanding. The Indonesian Realistic Mathematics Education (IRME) approach offers a promising solution as it emphasizes the use of real-life contexts as a bridge toward understanding abstract mathematical concepts (Van den & Drijvers, 2020).

However, the contexts typically used in teaching probability remain limited to traditional games or simple activities, such as snakes and ladders, dice throwing, or coin tossing. Few studies have explored the use of local cultural contexts as a medium for teaching probability. The Bekulo tradition in Rejang Lebong Regency, which embodies values of togetherness, deliberation, and decision-making, holds great potential to serve as a meaningful context for teaching combinations. Therefore, it is essential to design probability learning based on PMRI by utilizing the Bekulo tradition, enabling students not only to develop a deeper understanding of the concept of combinations but also to connect it with local cultural values that are relevant to their lives.

1.2. Related Research

Research on local cultural contexts has been shown to facilitate the modeling of abstract concepts while simultaneously enhancing student engagement in mathematics learning, as cultural practices provide authentic experiences that can serve as a bridge to formal understanding (Rosa et al., 2016; Ul-Haq, 2023). At the same time, international studies highlight that the use of contextual simulations and games is effective in improving probabilistic intuition and supporting students' transition from intuitive strategies to more formal combinatorial reasoning (Van den Heuvel-Panhuizen & Drijvers, 2020; Triliana & Asih, 2019). This underscores the importance of introducing authentic and enjoyable contexts that connect students' everyday experiences with the abstract concept of probability, thereby making learning not only more meaningful but also more relevant to their socio-cultural lives.

Nevertheless, previous studies have largely focused on error analysis or the development of generic learning modules without grounding them in specific local traditions, often relying on conventional game-based contexts. For example, Aisy et al., (2024) designed probability learning using IRME with the context of snakes and ladders; Sari et al., (2022) employed the context of the *ular naga* game; Kairuddin et al., (2024) used dice and coin tossing; and Ziliwu et al., (2024) applied Uno card games. Bibliometric reviews also indicate that although ethnomathematics has advanced significantly in Indonesia, few studies have combined IRME with in-depth instructional analysis on the probability subtopic of combinations using specific customary traditions (Rosa et al., 2016).

This study offers novelty by integrating the Bekulo tradition, a customary practice of the Rejang Lebong community that involves patterns of selection and grouping of components, as a cultural context for designing authentic combinatorial tasks. It further develops and validates a structured IRME-based instructional design in the form of a Hypothetical Learning Trajectory (HLT) aimed at guiding students' transition from intuitive strategies to formal combination procedures within a real cultural setting. In doing so, this research fills an existing gap in the literature—not merely applying IRME in general, but systematically constructing and testing an instructional model that draws on the structural features of local culture (Bekulo) to enhance students' understanding of combinations. This represents a novel contribution to probability education by integrating IRME and cultural traditions in an innovative way.

1.3. Research Objectives

The focus of this study is to design probability learning on the topic of combinations by integrating the cultural context of the Bekulo tradition from Rejang Lebong. The aim is to develop a meaningful instructional design that enables students to better understand the distinction between permutations and combinations, while also connecting abstract concepts to real-life situations. This study is expected to produce a learning design that enhances students' understanding of combinations, reduces conceptual and procedural errors, and fosters motivation and positive attitudes toward mathematics. In addition, the integration of the Bekulo tradition is anticipated to cultivate appreciation for local culture, thereby making mathematics learning more relevant and meaningful. The Bekulo tradition was selected as the context for probability learning on the topic of combinations because it has a strong structural correspondence with the mathematical concept of combinations. In the practice of the Bekulo tradition, there is a process of selecting a certain number of betel leaves from a set of available betel leaves contained in the *bokoa*. This selection process emphasizes the choice of elements from a set without considering the order, which is mathematically equivalent to the concept of combinations, namely selecting rrr objects from nnn objects without regard to order. This activity reflects the fundamental structure of combinations involving the selection and grouping of objects (Jones et al., 2007). Furthermore, the use of cultural practices as learning contexts supports the process of mathematization from informal situations to formal concepts, as emphasized in studies based on Realistic Mathematics Education, which show that meaningful contexts closely related to students' experiences can facilitate deeper understanding of probability concepts (Gravemeijer & Cobb, 2006). Compared to other cultural contexts that are more narrative or symbolic in nature, the Bekulo tradition naturally presents explicit elements of selection and grouping, making it more representative for supporting students in developing a meaningful conceptual understanding of combinations through a cultural context.

2. Theoretical Framework

2.1. Indonesian Realistic Mathematics Education (IRME)

Indonesian Realistic Mathematics Education (IRME) is an instructional approach adapted from the Dutch model of Realistic Mathematics Education (RME) (Sembiring, 2010). IRME views mathematics as a human activity; therefore, learning should begin with meaningful contextual problems that allow students to engage in both horizontal and vertical mathematization (Zulkardi, 2002). Through active participation in discussion, collaboration, and argumentation, students are encouraged to rediscover mathematical concepts independently(Johar et al., 2020; Widyastuti & Pujiastuti, 2014; Zubainur et al., 2020). In this way, IRME supports students in constructing deeper understanding, making learning more engaging, and enhancing their ability to apply mathematics in everyday life (Rifa'i & Anni, 2012).

2.2. Hypothetical Learning Trajectory (HLT)

Hypothetical Learning Trajectory (HLT) is an integral component of the Indonesian Realistic Mathematics Education (IRME) approach. HLT consists of three main components: learning objectives, planned learning activities, and hypotheses about students' learning processes (Putri, 2012; Susanto, et al., 2024). As part of IRME, HLT guides students through the process of mathematization from informal to formal stages, which include: (1) problem-solving based on real-life experiences, (2) model-of representing contextual activities, (3) model-for functioning as a mathematical thinking tool, and (4) formal stage with abstract understanding (Bakker, 2004; Gravemeijer and Terwel, 2000). HLT serves as an effective tool for designing mathematics instruction because it provides a systematic structure, fosters gradual knowledge development, and functions as a reflective instrument for teachers to evaluate students' understanding and improve learning (Cárcamo, et al., 2017; Huang et al. 2019). Thus, HLT plays a crucial role in creating mathematics learning that is more meaningful, adaptive, and aligned with students' cognitive development.

2.3. Probability

The concept of probability is one of the fundamental topics in mathematics that plays a crucial role in equipping students with probabilistic thinking skills. Research indicates that students' understanding of probability develops progressively, beginning with intuitive reasoning and advancing toward formal reasoning; therefore, probability instruction needs to be designed in alignment with students' cognitive development (Jones, et al., 2007). To support this process, the relationship between experimental and theoretical probability becomes essential, as direct experiments, simulations, and visual representations enable students to build a bridge from real-life experiences to formal mathematical models and probability distributions (Batanero et al., 2016). Furthermore, probability learning is more effective when it integrates interactive simulations, visual representations, and meaningful contexts, while also balancing the understanding of classical and frequentist perspectives of probability (Cai et al., 2023).

2.4. Bekulo Tradition

The Bekulo tradition is an important cultural practice of the Rejang community in Rejang Lebong Regency, typically performed during the marriage proposal process. Bekulo serves as a formal deliberation between the families of the prospective bride and groom to determine the wedding date, the amount of dowry or offerings, and to strengthen kinship ties. The procession begins with traditional greetings (*tegursapa adat*) and the ritual of *sirih izin*. During the *sirih izin* ceremony, community elders select betel leaves from a *bokoa* to chew. The *bokoa* traditionally contains seven betel leaves, lime, areca nut, gambier, tobacco, and cigarettes

3. Method

3.1. Research Design

This study employed a design research methodology with a validation study type, with the primary objective of developing a learning trajectory for the mathematical concept of combinations by integrating the Bekulo tradition as a cultural context. According to Gravemeijer, (2013), design research is an iterative and cyclical process that involves both the systematic design and empirical testing of learning activities and their accompanying pedagogical aspects. This method serves as a framework for developing instructional designs and supporting materials that focus on specific mathematical concepts. Its aim is to help students overcome learning difficulties, anticipate their possible responses, and foster more meaningful mathematical understanding.

The study adopted a qualitative research approach using a validation study design within design research. The learning trajectory for the probability subtopic of combinations, grounded in the Bekulo tradition, was developed through three main phases, as outlined by Gravemeijer & Cobb, (2006) and Van den Akker et al. (2006): preliminary design, design experiment, and retrospective analysis (See Figure 1).

In the preliminary design phase, a comprehensive literature review was conducted to establish the pedagogical relevance of combinations. This phase was followed by a series of focus group discussions (FGDs) involving mathematics educators, subject matter experts, and instructional designers. The outcome of these discussions was the initial design of the Hypothetical Learning Trajectory (HLT) and a set of Student Activity Sheets (SAS). The HLT, based on theoretical framework and further developed by Gravemeijer, (2004), contained a predictive sequence of learning experiences, including learning objectives, proposed activities, and anticipated student thinking and reasoning processes within the given instructional context.

The design experiment phase began with a pilot experiment aimed at gathering initial feedback to refine the instructional sequence using the Bekulo tradition for teaching combinations. This preliminary study functioned as a preparatory step for the main instructional experiment. The final phase, retrospective analysis, was conducted after the pilot and main teaching experiments. At this stage, systematic analysis was carried out on the empirical data collected, focusing on the comparison between the initially designed HLT and the Actual Learning Trajectory (ALT) that emerged during classroom implementation.

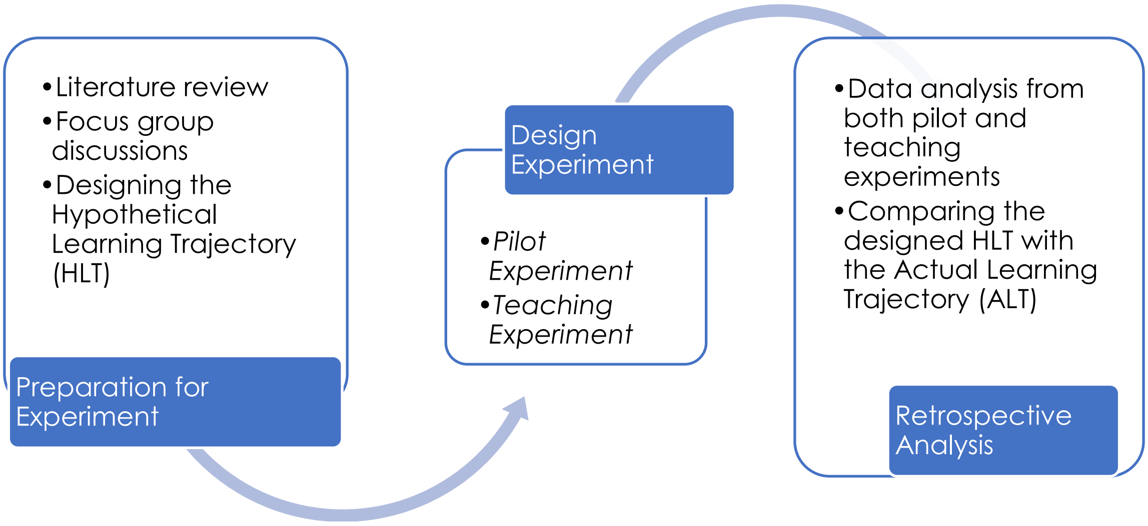


Figure 1. Stages of Design Research

3.2. Participant

This study involved ninth-grade students of SMP IT Salsabillah Rejang Lebong. In the pilot experiment phase, six students were selected through purposive sampling based on inclusion criteria aligned with the research objectives. Student participation was voluntary and had received ethical approval from the school authorities. The selection of participants considered variations in cognitive abilities, covering high, medium, and low categories. In the teaching experiment phase, the revised Student Activity Sheets (SAS) were implemented in one class.

3.3. Data Collection

The research instruments used in this study consisted of Student Activity Sheets (SAS) on probability with the cultural context of the Bekulo tradition and the Hypothetical Learning Trajectory (HLT). Data were collected through observation, documentation, and interviews.

3.4. Data Analysis

The collected data were analyzed using qualitative descriptive techniques. Qualitative descriptive analysis aims to describe, interpret, and understand phenomena based on the data obtained without applying statistical manipulation. In this approach, the researcher focused on the processes, meanings, and contexts emerging from the data, enabling a deeper understanding of participants' experiences and responses toward the designed learning trajectory. To ensure the trustworthiness of the qualitative data, several strategies were employed. Data triangulation was conducted by comparing data obtained from classroom observations, students' worksheets, and interviews to enhance the credibility of the research findings. In addition, peer debriefing was carried out through regular discussions with fellow researchers and supervisors to critically examine the data analysis process as well as the refinement of the Hypothetical Learning Trajectory (HLT). These strategies were implemented to strengthen the credibility, dependability, and confirmability of the qualitative findings within the design research framework.

4. Findings

4.1. Preparation Stage of the Experiment

The initial phase of this study began with the preparation stage of the experiment, which served as the foundation to ensure that all research components were systematically organized and aligned with the predetermined learning objectives. At this stage, the researcher conducted a comprehensive literature review by examining relevant sources, including documents from both the 2013 Curriculum and the *Merdeka Curriculum*. The review focused on analyzing the content of the combination topic, allowing the identification of conceptual requirements as well as potential difficulties students might encounter.

In addition, classroom observations were carried out to obtain a real picture of the learning conditions, teaching strategies, and student interactions in studying ratio and proportion concepts. These activities were further enriched by in-depth discussions with mathematics teachers as practitioners directly involved in classroom settings, ensuring that the feedback gathered reinforced the relevance and applicability of the instructional design. The findings from the literature review, classroom observations, and teacher discussions became the critical foundation for formulating the Hypothetical Learning Trajectory (HLT) and preparing Student Worksheets (SAS) to support the learning process.

Within the context of this study, the HLT functioned as a predictive conceptual framework that projected how students were expected to interact, think, and develop through a series of planned learning activities. The HLT was also designed to be flexible and dynamic, allowing revisions and adjustments based on empirical findings during implementation or outcomes from design trials (Juniarti et al., 2022). Thus, the HLT not only served as a guide for instructional planning but also as a reflective instrument to evaluate the achievement of learning objectives and the effectiveness of the strategies employed. The sequence of learning activities along with the anticipated student responses at each stage is systematically presented in Table 1.

Tabel 1. Hypothetical Learning Trajectory (HLT) for Probability: Combination

Learning Objectives	Learning Activities	Hypothetical Student Responses
Identifying the concept of combinations and their characteristics	1. Students observe a video of the Bekulo tradition in Rejang Lebong Regency. 2. Students discuss the information obtained from the Bekulo tradition and identify objects selected in the ceremony. 3. Students identify the number of betel leaves in the *bokoa* and the number of leaves to be selected. 4. Students compare the rules of arrangement in permutation and combination.	1. Students observe the Bekulo tradition attentively. 2. Students are able to identify contextual information about the activities in the Bekulo tradition. 3. Students are able to determine the total number of betel leaves and the number to be selected. 4. Students can identify the differences between permutation and combination, leading to an understanding of the concept of combination and its characteristics.
Determining the value of combinations in a given problem	1. Students conduct an experiment in groups, simulating the selection of 2 replica betel leaves from the *bokoa*.	1. Students are able to conduct the experiment with peers. 2. Students record their results in the provided table.

Learning Objectives	Learning Activities	Hypothetical Student Responses
	2. Students record the results of the experiment in a table provided by the teacher. 3. Students list all possible outcomes. 4. Students calculate the total number of possibilities. 5. Students identify the relationship between permutation and combination. 6. Students calculate the number of ways to choose 2 betel leaves from 7 in the *bokoa*. 7. Students complete the table with their results.	3. Students identify the possible outcomes of drawing 2 leaves (e.g., 3 red and 4 green). 4. Students correctly record all possible outcomes. 5. Students calculate the total number of outcomes 6. Students understand that in combinations, order does not matter, e.g., (M1, M2) = (M2, M1). 7. Students are able to calculate the number of ways to choose 2 leaves from 7. 8. Students formulate the results in the table but may struggle to identify broader relationships. 9. Students are able to formulate the calculation results into a table. 10. Students are able to complete the table but are not yet able to identify the underlying relationships. 11. Students discover the formula for calculating combinations of *r* objects from *N* objects. 12. Students are not yet able to derive the formula for combinations of *r* objects from *N* objects.

The HLT was developed by adopting recent advancements in mathematics education and instructional design, as presented in Table 1. The revision process was carried out in stages through focus group discussions (FGDs) with two mathematics education experts and one instructional design specialist. Through this collaborative review, valuable input was obtained to ensure theoretical consistency, contextual relevance, and clarity of instructions. As a result, the HLT was refined and finalized to align with pedagogical principles within the framework of IRME.

This HLT played a role in creating meaningful learning experiences by connecting students' prior knowledge with real-life contexts. This is consistent with Ausubel's theory of meaningful learning, in which students can build cognitive bridges between new mathematical concepts—particularly combinations—and their existing intuitive experiences and understandings (Hasbi et al., 2019). Subsequently, a pilot test was conducted with six ninth-grade students of varying academic abilities. In this phase, the HLT was implemented in a controlled learning setting to evaluate its effectiveness and to obtain initial findings regarding student engagement and learning development.

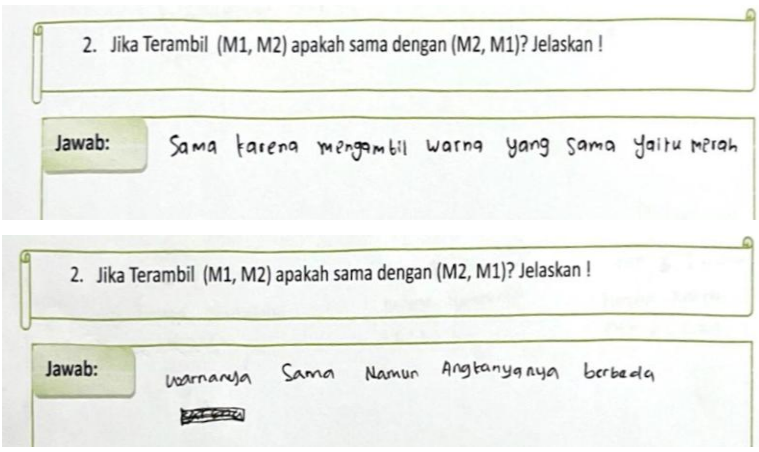
4.2. Design Experiment Phase

The design experiment phase in this study began with a pilot experiment. At this stage, the researcher obtained an initial overview of students' learning trajectories through an analysis of their responses to the Student Activity Sheets (SAS) that had been designed during the preparation phase. The pilot experiment involved six ninth-grade students with varying cognitive abilities—high, medium, and low.

The implementation of the pilot experiment aimed to identify possible learning trajectories that emerged and to compare them with the initial HLT that had been developed. In addition, this phase served to collect empirical data as a basis for revising the HLT, thereby ensuring that the instructional design would be more relevant to students' characteristics. During the activities, the researcher observed students' interactions in completing the SAS, focusing on their problem-solving strategies, group discussions, and the challenges they encountered.

In the initial activity (Activity 1), students began by watching a video of the Bekulo tradition in Rejang Lebong Regency (https://www.youtube.com/watch?v=EHKZ4Cnz4vU&t=56 Through this video, students were guided to carefully observe each stage of the Bekulo tradition and then identify important information related to the cultural practices. The main objective of this activity was to enable students to connect contextual information from the Bekulo tradition with probability concepts, particularly the topic of combinations. In this way, students not only became familiar with their local tradition as part of their cultural heritage but also learned to identify mathematical problems that could be modeled from real-life situations.

Subsequently, students were asked to formulate problems relevant to the concept of combinations based on their observations of the video. This stage also functioned as training in linking cultural experiences with mathematical representations. The results and findings of students in the pilot experiment, as expressed in their responses on the SAS, are presented in Figure 2.



2. If (M1, M2) is selected, is it the same as (M2, M1)? Explain!

Student A's Answer: They are the same because the same colors are selected, namely red.

Student B's Answer:

The colors are the same, but the elements are different.

Figure 2. Students' Responses in Identifying the Concept of Combination

Students' responses in Figure 2 indicate the presence of initial misconceptions related to the concept of combinations, particularly in distinguishing between combinations and permutations. Student response (a) is categorized as an attribute-based misconception**,** in which the student stated that the pairs (M1, M2) and (M2, M1) are the same because they have the same color of betel leaves, without considering the mathematical structure of selection without regard to order. Meanwhile, student response (b) reflects an object-identity-based misconception, where the student considered the pairs to be different because the selected elements were not identical, even though the problem context emphasizes that the order of selection is irrelevant. These findings indicate that students are still at an early stage of understanding combinations and have not yet fully internalized the principle that "order does not matter" in combinations. Within the IRME framework, these student responses suggest that the models used by students still function as models-of the contextual situation, focusing on the concrete characteristics of the betel leaves (such as color and identity), and have not yet developed into models-for formal mathematical reasoning about combinations. The transition from model-of to model-for begins to emerge when, through classroom discussions and teachers' reflective questions, students start to realize that the focus in combinations lies on the number and type of objects selected rather than the order of selection. Accordingly, this analysis confirms that the Bekulo cultural context plays an important role as a conceptual bridge in facilitating students' shift from intuitive reasoning toward a formal understanding of the concept of combinations. The following excerpt presents part of the interview with student (b).

Researcher	: "For the second group, you answered that the color is the same, but the members are different. Could you explain what you meant by that answer?" Student : "What I meant is, for example, if we take the first red leaf and the second red leaf, the color is the same—both are red—but I thought they are different because the members are not the same."
Researcher	: "So, in your opinion, is the arrangement (M1, M2) different from (M2, M1)?"
Student	: "Yes, different, because the betel leaves selected are different even though they have the same color."
Researcher	: "In combinations, do you think what matters is the order, or rather the quantity and type of items selected?"
Student	: "(pauses for a moment) In combinations, maybe it's just the quantity and color, not the order… but I'm not very sure."

In Activity 2, students began by answering questions related to problems within the Bekulo tradition and were then instructed to conduct an experiment by simultaneously drawing two betel leaves from the *bokoa*. The researcher identified several difficulties experienced by students in this activity, as illustrated in Figures 3 (a) and (b).

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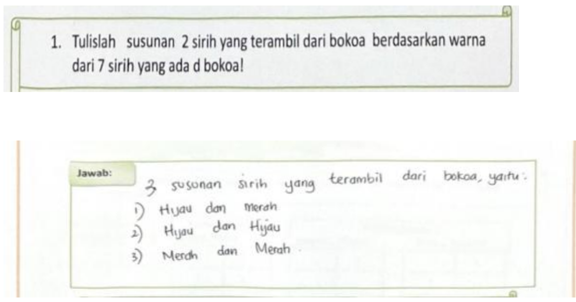
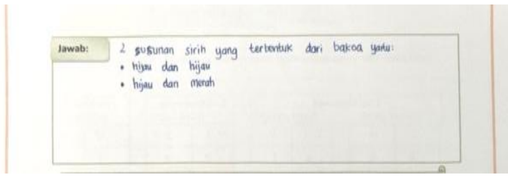


(a)


(b)
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Problem:
Tanda Rajo gives permission to start the ceremony by taking two betel sticks from the bokoa and eating them. How many possible arrangements of two betel sticks can Tanda Rajo make when selecting the betel sticks from the bokoa?
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1. Write two arrangements of betel sticks taken from the bokoa based on the colors of the seven betel sticks in the bokoa.
Student A's answer:
Three arrangements of betel sticks taken from the bokoa are:
1. green and red,
2. green and green,
3. red and red.
Student B's answer:
Two arrangements of betel sticks formed from the bokoa are:
</td>
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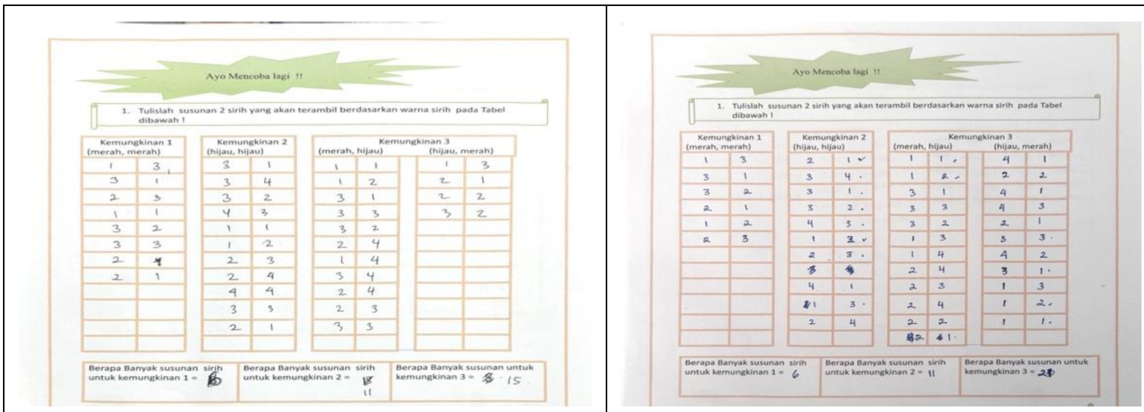
</table>

	1. green and green, 2. green and red.

Figure 3. Students' Responses to Question 1 in Activity 2

Figure 3(a) shows that the student was able to calculate the number of possible color arrangements when selecting 2 betel leaves from a total of 7 leaves in the basket, consisting of 3 red leaves and 4 green leaves. Such a response reflects a correct understanding of the concept of combinations. In contrast, Figure 3(b) illustrates an incorrect response; although the student listed several possible outcomes, the group failed to identify all valid combinations. After a discussion with the researcher, the student was able to understand the complete solution and correct their mistake. This difficulty reflects a common phenomenon in learning the concept of combinations: students often struggle to distinguish between combinations and permutations and tend to make errors in carefully enumerating all possibilities (Matitaputty et al., 2022). Another set of difficulties was also observed during the experiment of selecting 2 betel leaves from the *bokoa*, as shown in Figures 4(a) and (b).



(a) (b)

Let's Try Again!!

1. Write down the arrangements of 2 betel leaves that will be picked based on the color of the leaves in the table below!

- Possibility 1 (Kemungkinan 1): (red, red) / (merah, merah)
- Possibility 2 (Kemungkinan 2): (green, green) / (hijau, hijau)
- Possibility 3 (Kemungkinan 3): (red, green) / (merah, hijau) & (green, red) / (hijau, merah)

Student A's answer:

- How many arrangements for possibility 1 = 8
- How many arrangements for possibility 2 = 11
- How many arrangements for possibility 3 = 15

Student B's answer:

- How many arrangements for possibility 1 = 6
- How many arrangements for possibility 2 = 11
- How many arrangements for possibility 3 = 21

Figure 4. Students' Responses in the Experiment Activity

Figure 4 (a) and (b). These figures illustrate students' errors in filling in the columns provided in the SAS, which were based on the results of the experiment of drawing two betel leaves from the *bokoa*. As shown in Figure 4, students were less careful in recording the experimental outcomes and were unable to fully analyze the possible results. Consequently, many columns that could have been filled remained incomplete, as students stopped the experiment prematurely. However, in the first table for Case 1, students were able to identify all possibilities. When asked for clarification, students explained that this was because the sample space was relatively small, making it easier for them to identify all outcomes. In contrast, for Cases 2 and 3, the sample space was larger, which caused students difficulties in identifying all possibilities. The following excerpt presents part of the interview between the researcher and the students.

Researcher : "Why did you only fill in part of the results in the SAS table and not continue until all columns were completed?"

Student : "I felt it was enough, Ma'am. After trying several times, I thought the results would be the same, so I stopped."

Researcher : "But there were still some possibilities that were not written. In your opinion, why did that happen?"

Student : "I wasn't careful enough, Ma'am. I got confused when there were too many choices. So I just wrote down the ones that seemed easier."

Researcher : "Looking at the table, in the first case you managed to list all the outcomes completely. What made you able to do that?"

Student : "Because the choices were fewer, Ma'am. The sample space was small, so I could quickly see all the possibilities."

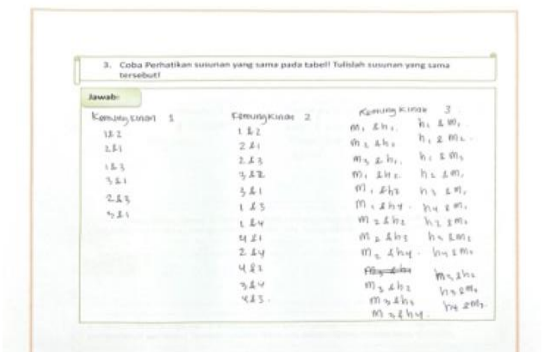
Researcher : "Then why were there many empty columns in the second and third cases?"

Student : "Because there were more choices, Ma'am. I got confused and found it difficult to make sure that everything had been recorded. So I stopped halfway."

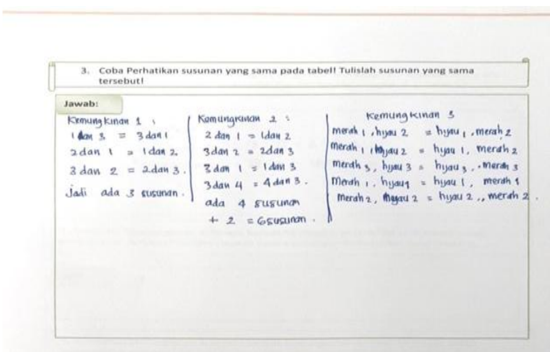
Researcher : "In that case, what do you think could help make it easier to identify all possibilities in a larger sample space?"

Student : "Maybe if there were clearer steps or a more systematic method, Ma'am, so it wouldn't be confusing and I could be more accurate."

Another finding observed by the researcher can be seen in **Figure 5**.



(a)



(b)

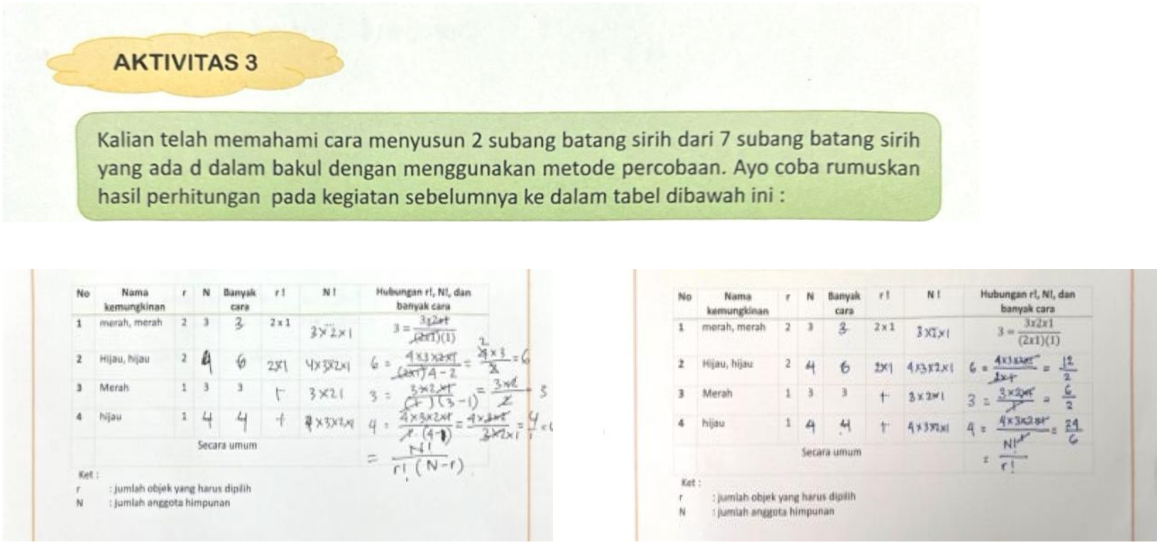
3. Observe the identical arrangements in the table! Write down those identical arrangements!

Figure 5. Students' Responses to Question 3 in Activity 3

In Figure 5 (a) and (b), students were asked to rewrite the experimental data and identify the arrangements formed by selecting 2 betel leaves from 7 leaves in the *bokoa*. Students would be able to answer Question 3 correctly if they had already understood the concept of combinations. As seen in Figure 5, the student had demonstrated an understanding of combinations and had recognized the difference between the concepts of combination and permutation. However, the student was still not sufficiently careful, resulting in incomplete responses, as some outcomes considered to be the same were not recorded in the provided table. The following excerpt presents part of the interview between the researcher and the student.

Researcher	: "Can you explain how you wrote the arrangements of 2 betel leaves selected from 7 leaves in the *bokoa*?"
Student	: "I tried to write the possible pairs of leaves that could be taken, Ma'am. I thought that if the colors were the same, then the arrangements were also the same."
Researcher	: "Do you know the difference between combinations and permutations?"
Student	: "Yes, Ma'am. In combinations, the order does not matter. In permutations, the order is counted as different."
Researcher	: "If that's the case, why were there still some experimental results that you didn't write down?"
Student	: "Because I thought they were the same, Ma'am. So I didn't write them again. Maybe I wasn't careful enough—I thought it wasn't necessary to list them all."
Researcher	: "Do you think writing down all the possibilities is important in solving combination problems?"
Student	: "Yes, it's important, Ma'am, so nothing is missed. But sometimes I'm in a hurry, so I only write down part of them."
Researcher	: "What do you think could help you be more careful in writing down all the results of the experiment?"
Student	: "Maybe it should be made more systematic, Ma'am, for example by listing each pair one by one in a certain order so that nothing is left out."

At the end of Activity 3, students were asked to formulate all possible outcomes into a table with the aim of enabling them to identify the formal mathematical structure of combinations. The results of students' work at the end of Activity 3 are presented in Figure 6.



(a) (b)

(Activity 3) You have understood how to arrange 2 betel leaf stalks from the 7 betel leaf stalks in the basket using the experimental method. Let's try to formulate the calculation results from the previous activity into the table below:

Figure 6. Students' Responses in Activity 3

Figure 6(a) and 6(b) show the results of students' work at the end of Activity 3. In Figure 6(a), the student was able to analyze the elements in the table and successfully derive the formal expression for calculating combinations. In contrast, Figure 6(b) shows that the student was able to compl ete the table by analyzing its elements but still made errors in formulating the general structure of combination calculations. From the students' responses in the Student Activity Sheet (SAS), it can be seen that they generally understood the question well. However, when writing their answers, they were not sufficiently careful and failed to present all the possible outcomes that should have been listed. In addition, limitations in analytical skills also became a major factor causing errors in solving combination problems. The researcher conducted an interview with the student regarding the steps of completing the table, as follows:

Researcher : "How did you complete the table?"

Student : "By observing the parts of the table, Ma'am, based on the instructions provided in it."

Researcher : "Based on the instructions in the table, were you able to identify the relationships among the elements in the table?"

Student : "To fill in the table, we followed the instructions, Ma'am, but we had difficulties in understanding the relationship between *N* and *r*."

Researcher : "Alright, let's look at the table. In your opinion, what do *r* and *N* mean as written in the notes below the table?"

Student : "*r* is the number of objects to be chosen, and *N* is the total number of members. Is that correct?"

Researcher : "Exactly! So, for the first row, where it shows 'red, red' with *r* = 2 and *N* = 3, how should the number of ways be calculated?"

Student : "I was confused before, Ma'am… maybe I will understand it better after reviewing it again."

During the *pilot experiment* phase, the study involved six students purposively selected to represent diverse levels of mathematical ability**.** The use of a small number of participants is consistent with the principles of *design research*, in which the primary objective of the initial phase is to conduct an in-depth exploration of students' thinking processes, identify potential misconceptions, and evaluate the feasibility and clarity of the instructional design. Data derived from students' responses and interactions in this phase served as the basis for revising the learning activities and refining the student worksheets. Subsequently, in the *teaching experiment* phase involving 25 students from a single intact classroom, the revised *Hypothetical Learning Trajectory* (HLT) and instructional materials were implemented to examine the coherence of the learning trajectory, the practicality of the design, and its validity within an authentic classroom context. At this stage, students demonstrated improved conceptual understanding and greater engagement in learning. The adjustments made based on the pilot experiment enabled students to analyze images more easily, understand video content, and respond more accurately to guided questions.

As a result, students were able to more accurately identify the relationship between combinations and outcomes within the context of the Bekulo tradition. They also demonstrated the ability to construct logical and consistent arguments based on data. Errors that had previously appeared during the pilot stage, such as misconceptions of the concept, were gradually resolved. The inclusion of guiding questions proved effective in clarifying concepts, increasing accuracy, and deepening students' understanding of mathematical relationships within real-life contexts.

Figure 7. Teaching Experiment in the Larger Group

The implementation of learning activities in this study was grounded in the Hypothetical Learning Trajectory (HLT), which was subsequently refined through retrospective analysis by comparing the HLT with the Actual Learning Trajectory (ALT). These improvements were supported by mathematics education theory, including the principles of Indonesian Realistic Mathematics Education (IRME) and findings from previous studies. The cultural context, particularly the Bekulo tradition of the Rejang ethnic community, served as the starting point of the learning process. The selection of a context closely related to students' lives aligns with research findings indicating that student engagement and understanding improve when learning is connected to real and meaningful experiences (Zulkardi, 2013). This demonstrates that the HLT is effective in supporting students' conceptual development in accordance with the principles of IRME.

5. Discussion

Based on the results of the retrospective analysis, which involved a comparison between the Hypothetical Learning Trajectory (HLT) and the Actual Learning Trajectory (ALT) as well as relevant theories concerning probability in the subtopic of combinations and the IRME approach, it can be concluded that the designed HLT was effective in guiding students through the stages of learning in accordance with the principles of IRME. The learning process began with the cultural context of the Bekulo tradition in Rejang Lebong Regency, which then led students through the processes of horizontal and vertical mathematization, culminating in the formal representation of the concept of combinations. This finding is consistent with Putri et al. (2024), who stated that learning through IRME and the use of contextual problems in probability topics supports students' understanding and enables them to solve real-life problems related to probability.

The integration of IRME with cultural aspects also proved to be an effective strategy for improving mathematical ability, particularly critical thinking skills (Domu & Mangelep, 2023; Shahidayanti et al., 2024). The learning trajectory in this study developed in stages consistent with the IRME framework, beginning with the concrete and contextual phase, continuing with horizontal and vertical mathematization, and culminating in the stage of abstract formalization (Zulkardi, 2013). In the concrete phase, students were directly engaged through real-life experiences, such as watching a video of the Bekulo tradition, which enabled them to connect mathematics with everyday life. This engagement helped students understand how to arrange and select the betel leaves contained in the *bokoa*, while reinforcing the idea that mathematics functions as a tool to explain and solve real-world problems (Mumu & Tanujaya, 2019). Afterward, students were guided to use visual representations.

From a theoretical perspective, the findings of this study contribute to the development of Hypothetical Learning Trajectories (HLT) within the framework of Indonesian Realistic Mathematics Education , particularly in probability learning on the topic of combinations. This study extends previous HLT research by demonstrating that local cultural contexts do not merely function as contextual illustrations, but also serve as key drivers of students' progressive mathematization processes. These findings are consistent with international studies emphasizing that learning trajectories designed around meaningful contexts can effectively support students' gradual transition from informal understanding to formal mathematical reasoning (Gravemeijer & Cobb, 2006).

In contrast to probability-related HLT studies that typically employ game-based contexts, random experiments, or general everyday situations, this study highlights that local cultural traditions, such as the Bekulo tradition, can structure a systematic sequence of learning activities that guide students from informal situations toward a formal understanding of the concept of combinations. This supports (Bishop, 1991), view that cultural practices can serve as powerful conceptual resources in mathematics learning and contribute to deeper conceptual meaning-making. Accordingly, this study enriches the IRME-probability learning literature by providing empirical evidence that integrating local cultural contexts into HLT design not only enhances the meaningfulness of learning but also advances theoretical understanding of the role of context in probability learning.

6. Conclusion

The results of this study indicate that the developed learning trajectory was effective in supporting students' understanding of probability concepts, particularly on the topic of combinations, through the context of the Bekulo tradition in Rejang Lebong Regency. The designed learning activities enabled students to solve probability problems in a more meaningful way. Furthermore, the use of the Bekulo tradition as a context in the PMRI-based HLT design proved to be relevant and effective in enhancing students' conceptual understanding. From a theoretical perspective, this study contributes to the development of Hypothetical Learning Trajectories (HLT) within the Indonesian Realistic Mathematics Education (IRME) approach. The findings demonstrate that local cultural contexts can be utilized as effective learning contexts to connect students' lived experiences with probability concepts. This study reinforces the PMRI perspective that the use of contexts closely related to students' lives plays a crucial role in supporting the gradual development of mathematical understanding. From a pedagogical perspective, the findings provide practical implications for teachers and curriculum designers. For teachers, the developed learning trajectory can be used as an alternative framework for designing more contextual and meaningful probability instruction. The integration of the Bekulo tradition helps increase student engagement and promotes conceptual understanding beyond a mere focus on computational procedures. For curriculum designers, this study highlights the importance of incorporating local cultural contexts into mathematics instruction to ensure that learning materials are more relevant to students' experiences. Overall, this study suggests that IRME-based probability learning that integrates local cultural contexts can serve as an effective strategy for improving the quality of mathematics instruction.

Limitation

This study has several limitations related to the generalizability of its findings. First, the implementation of the Bekulo-based HLT was conducted in only one class with a limited number of students within a specific cultural context. Therefore, the findings cannot be directly generalized to other educational or cultural settings, as the effectiveness of the learning trajectory depends on students' familiarity with the Bekulo tradition. Second, although the Bekulo cultural context proved effective in this study, its application to other cultural contexts requires careful adaptation, since not all cultural practices share the same structural alignment with the concept of combinations, particularly elements of selection and grouping. Third, this study focused solely on the topic of combinations and employed relatively simple learning media, thus not addressing other probability topics or the potential use of more interactive technological tools. Future research is recommended to examine the applicability of the developed learning trajectory across diverse cultural contexts, with broader participant samples, and to extend its implementation to other probability topics and technology-enhanced learning environments.

Recommendation

Future research is recommended to incorporate a wider variety of activities in the HLT that are more diverse and challenging, thereby enriching students' learning experiences and enhancing the effectiveness of the learning trajectory. These additional activities may include the exploration of other cultural contexts relevant to students' daily lives, the use of interactive technology-based learning media, as well as the integration of collaborative tasks that encourage discussion and joint problem-solving. In this way, the developed HLT would not only deepen students' conceptual understanding of probability but also foster critical thinking, mathematical communication, and collaboration skills in the learning process.

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Conflict of Interest Statement

The author(s) declare(s) that there is no conflict of interest.

Declaration of Generative AI and AI-assisted Technologies

This manuscript was prepared with the assistance of Generative AI such as ChatGPT, Grammarly, and Translator). The AI was used to assist in drafting and language refinement. All intellectual contributions, critical analyses, and final revisions were conducted by the authors. The authors take full responsibility for the accuracy, originality, and integrity of the content presented in this work.

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