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# The Learning Trajectory on Integer Operations Material Using *Sagele* Dance

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***Abstract***

Traditional Indonesian dances can serve as meaningful contexts for mathematics instruction, yet this potential remains underutilized in many classrooms, including in West Nusa Tenggara. This study aims to design a learning trajectory for integer operations by integrating *Sagele* dance, which features rhythmic forward and backward movements suitable for representing positive and negative numbers. Employing a design research methodology, data were collected through video recordings, field notes, questionnaires, and classroom observations. The study followed three key phases: preliminary design, design experiment, and retrospective analysis. The resulting trajectory consists of three learning activities: (1) exploring free movement in *Sagele* dance to emphasize directional shifts; (2) combining directional changes to illustrate integer operations; and (3) formalizing these concepts through number line models corresponding to the dance movements. Findings show that integrating the *Sagele* dance helped students transition from informal to formal mathematical thinking, supporting both conceptual understanding and character development, such as respect for cultural heritage. The cultural contextualization also enhanced student engagement and supported the internalization of abstract operations. This research offers a replicable model for incorporating ethnomathematics into classroom practice. While limited in scope and sample size, the study highlights the promise of culturally grounded learning trajectories in mathematics education and calls for broader application in future research.

**Keywords:** Ethnomathematics, Integer Operations, Learning Trajectory, *Sagele* Dance

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## INTRODUCTION

Mathematics is a fundamental component of science and a vital aspect of everyday life, intrinsically connected to human activities and decision-making processes (Eshaq, 2023; NCTM, 2000). However, its abstract nature often presents significant challenges for students, particularly in grasping complex concepts such as integer operations (Khalid & Embong, 2020). To address these difficulties, the integration of mathematical concepts with cultural contexts has been proposed as an effective strategy to broaden students' perspectives, thereby enhancing comprehension and engagement (Kusuma et al., 2024). Ethnomathematics—the study of the relationship between mathematics and culture—offers an innovative approach for contextualizing abstract mathematical ideas within students' cultural frameworks, making them more accessible and meaningful (Ergene et al., 2020). For instance, the concept of integer division can be effectively represented through local cultural practices, such as dividing ingredients during the preparation of traditional Nusantara cakes (Nuraida & Putri, 2019).

To enhance students' understanding of mathematical concepts, it is essential for teachers to design learning tasks that are both meaningful and culturally relevant. An effective approach involves transforming traditional cultural elements, such as dance, into instructional tools that embody

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mathematical thinking (Nur et al., 2022). By integrating formal mathematical ideas with real-life experiences—such as traditional games or cultural practices—students are provided with concrete contexts that support deeper conceptual understanding (Dominikus, 2023; Gravemeijer, 2020). Culturally rooted games, in particular, can be adapted to naturally represent mathematical concepts such as numbers, patterns, and geometry in ways that are enjoyable, accessible, and contextually meaningful (Risdyanti & Prahmana, 2020; Wibawa et al., 2022).

Observations conducted in several elementary schools revealed that sixth-grade students faced difficulties in understanding integer operations, particularly with negative numbers. The learning process remained largely teacher-centered and reliant on textbooks, with minimal incorporation of concrete representations or local cultural contexts. Paliwal & Baroody (2020) identified the abstract presentation of negative numbers as a primary obstacle, while Dominikus (2023) emphasized the lack of contextual learning materials as a contributing factor to students' low conceptual understanding and motivation. These findings highlight the need for alternative instructional approaches that connect mathematics to students' cultural experiences. Integrating local cultural practices, such as traditional games or dances, is considered an effective strategy to present abstract concepts in a more contextualized and meaningful manner (Ergene et al., 2020; Kusuma et al., 2024).

The integration of cultural elements into mathematics education yields several benefits, including increased motivation and academic performance. By connecting mathematical concepts with familiar cultural practices, such as traditional dances, students can find greater relevance and meaning in their studies (Nur et al., 2022). Despite its advantages, mathematics learning still faces challenges, particularly among elementary students in understanding integer operations (Hernandez & Burrows, 2021). Limited conceptual understanding often leads to misconceptions, such as confusion between operational signs and negative values, as well as a tendency to memorize rules without deep comprehension (Khalid & Embong, 2020). To address this, contextual and culturally based instructional strategies are needed to bridge conceptual gaps and reduce misconceptions (Fuadiah et al., 2019; Utami et al., 2018).

The *Sagele* dance, as a form of traditional cultural expression, represents the values and social cohesion of the community from which it originates. Passed down through generations, this dance is performed during major communal events. It serves not only as an artistic performance but also holds potential for integration into educational contexts (Syaifuddin et al., 2021). In this regard, the integration of ethnomathematics into mathematics education has been shown to improve students' learning outcomes and problem-solving abilities by connecting abstract material to familiar cultural contexts (Permana, 2023). The rhythmic movements of the *Sagele* dance—such as forward and backward motions—can be contextualized within the learning of integer operations, with forward movements representing positive integers and backward movements representing negative ones. In practice, students can perform these movements in groups while solving contextual problems. This approach enables students to understand mathematical concepts through kinesthetic and visual experiences, while

also fostering meaningful mathematical associations within their cultural framework. Such integration not only enhances conceptual understanding but also contributes to the preservation and appreciation of local cultural heritage (Ergene et al., 2020).

Learning trajectories provide a structured approach to understanding the sequence of mental and physical activities that students undergo while learning a concept (Bakker, 2019; Gravemeijer & Cobb, 2006). Incorporating cultural contexts into these trajectories has proven effective in improving student engagement and understanding of mathematical concepts. Previous studies have demonstrated the efficacy of using local cultural practices, such as traditional games and stories, to teach mathematics, but research on using traditional dances, particularly the *Sagele* dance, remains limited (Ilma, 2024). This gap highlights the need for further exploration of how learning trajectories can be developed using regional dances to teach specific mathematical operations.

This study aims to address this research gap by exploring the integration of the *Sagele* dance into a learning trajectory for integer operations. The objective is to describe the process through which student progress from informal understanding to formal mathematical concepts, leveraging the cultural and educational potential of the *Sagele* dance. This research contributes to the growing body of knowledge in ethnomathematics, offering innovative insights into how cultural contexts can enhance mathematics education while preserving local traditions (Khalid & Embong, 2020; Laamena & Laurens, 2021). Through this approach, the study seeks to provide an alternative method for teaching mathematics that is both culturally relevant and pedagogically effective. Thus, the purpose of this study is to describe the design of a learning trajectory on integer operations material using the traditional *Sagele* dance. The research question is: how is the design of a learning trajectory on integer operations material using the traditional *Sagele* dance developed based on the stages of preliminary design, design experiment, and retrospective analysis.

## METHODS

This study employed the design research method, a systematic and iterative approach aimed at improving the quality of learning within the classroom (Gravemeijer & Cobb, 2006; van den Akker et al., 2010). This method enables collaboration between researchers and teachers to develop, implement, and refine educational designs that address specific learning challenges (Bakker, 2019). The framework is particularly well-suited for exploring and contextualizing mathematical concepts within cultural settings, as it emphasizes the dynamic interaction between instructional strategies and student learning outcomes (Kafyulilo & Fisser, 2019; Karunanayaka & Naidu, 2017).

The design research methodology integrates two primary components: Hypothetical Learning Trajectories (HLT) and Learning Trajectory (LT). HLT represents the teacher's anticipations regarding mental activities that may arise during the learning process (Turgut et al., 2021). It serves as a guideline for predicting students' responses and understanding as they engage with the material (Prahmana, 2017).

LT on the other hand, offers a comprehensive framework for describing learning trajectories, encompassing theoretical foundations and practical insights. LT represents the final product of iterative HLT refinements, developed, implemented, and analyzed to improve learning outcomes (Ramadhani et al., 2024). These theoretical structures underpin the design and implementation of culturally contextualized educational practices. The study progressed through three stages in alignment with the design research framework: preliminary design, design experiment, and retrospective analysis can be illustrated on Figure 1.

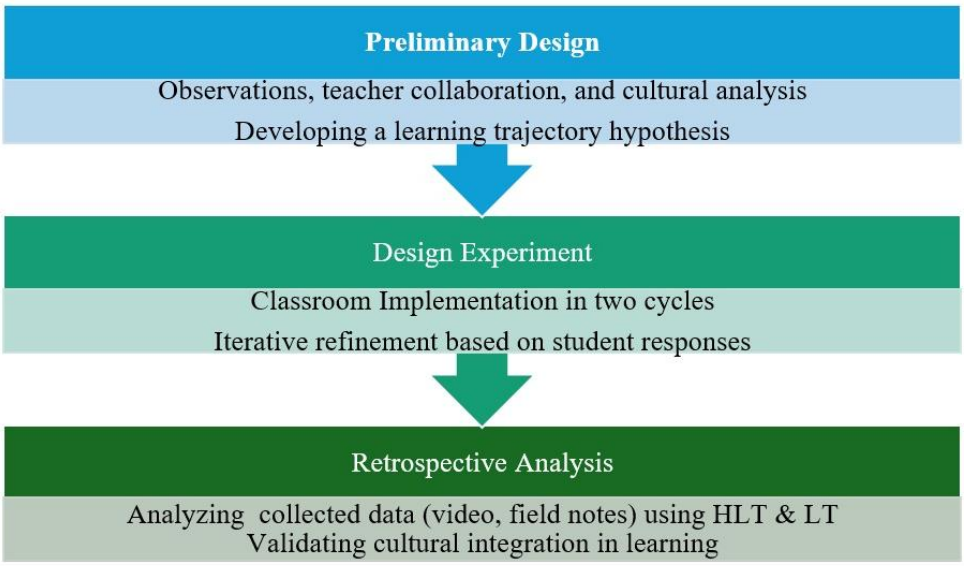


**Figure 1.** The stage of design research

***Preliminary Design***

The preliminary design stage involved observations and discussions to establish the foundational framework for the study. Researchers collaborated with teachers at SDN 1 Maria in Bima NTB to analyze students' initial understanding of integer operations, their cultural experiences, and existing instructional practices. These observations revealed that students struggled with integer operations and relied heavily on textbook-based learning, lacking engagement with local cultural contexts.

To address these challenges, the researchers introduced the traditional *Sagele* dance as a medium to contextualize integer operations. Collaborative discussions with teachers resulted in the creation of a learning trajectory design, rooted in cultural relevance and aligned with the principles of HLT. This design served as a hypothesis for guiding the learning process and was subject to ongoing revisions during implementation. These iterative adjustments ensured that the trajectory remained responsive to students' evolving needs and contextual realities (Cavanagh et al., 2020). The learning conjecture on the topic of integer operations using the context of the *Sagele* dance is presented in Table 1.

**Table 1.** Learning conjecture on integer operations using the *Sagele* dance context

| Stage | Activity Description | Conjecture |
|---|---|---|
| Activity based on experience (Informal) | Activity 1**:** Identifying integer directions through *Sagele* dance with free movement dance.<br><br>Description:<br>*Sagele* dance movements are performed with the aid of a number line medium (number posters connected using string). Two students hold the number line posters, while four others perform forward/backward steps and left/right turns. | 1. Students begin to recognize that forward movements represent positive integers and backward movements represent negative integers.<br>2. Students are not yet able to consistently associate left and right directions with addition and subtraction operations.<br>3. Students begin to develop an intuitive understanding of integer concepts through kinaesthetic experience |
| Connecting activity (Referential) | Activity 2**:** Structured and modified choreography of *Sagele* dance to make model of operations<br><br>Description:<br>Students perform the *Sagele* dance based on agreed-upon rules: (1) the dancer's initial position is at number 0, facing right; (2) the *Sagele* dance movements combine forward or backward steps with left or right turns; (3) the final position of the dancer represents the result of the operation. | 1. Students are able to follow the choreography rules and begin to visually model integer operations through movement.<br>2. Students occasionally make errors in determining direction or number of steps, indicating that their conceptual understanding is still developing.<br>3. Students are able to explain the results of addition and subtraction operations using dance movement narratives. |
| Formal cctivity | Activity 3: Modelling using a number line.<br><br>Description:<br>Students model integer operations using a number line based on their movement experiences in the *Sagele* dance (jumps forward or backward) and complete exercises involving integer operations. | 1. Students are able to map dance movements onto a number line and formally solve integer operations.<br>2. Students demonstrate an increased conceptual understanding, progressing from intuitive to abstract thinking.<br>3. Students can explain the mathematical reasoning behind the results, including the final position and direction of movement. |

***Design Experiment***

This study adopted a design experiment approach consisting of two cycles to develop, implement, and refine a learning trajectory for integer operations based on local cultural contexts through the *Sagele*

dance. 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 15 students from SDN 1 Maria in Bima Regency, aged 11–12 years. Students were categorized into three groups based on their Initial Mathematical Ability (IMA): high, medium, and low, with five students in each group. This classification aimed to capture the learning responses across varying ability levels. During this cycle, the initial Hypothetical Learning Trajectory (HLT) was implemented through three stages of instruction. Based on the insights and challenges identified in 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 class within the same school, involving 28 students with a similar diversity in mathematical ability levels. The revised HLT was re-implemented following the same three stages of instruction. This cycle placed greater emphasis on role distribution (dancers, singers, and number line holders) and promoted collaborative interaction among students.

Data were collected throughout both cycles using video recordings, field notes, photographic documentation, student worksheets, observation sheets, student feedback forms, and post-activity interviews. These instruments captured students' learning processes, engagement levels, and challenges, particularly their difficulties in applying directional rules and transitioning from kinesthetic experiences to symbolic representations. The collected data were systematically analysed to identify patterns of misunderstanding and areas requiring support. Insights from this analysis directly informed the revision of the Hypothetical Learning Trajectory (HLT), leading to clearer movement instructions, improved role distribution, enhanced instructional materials, and better integration of cultural elements.

### *The Retrospective Analysis*

After the teaching experiment was conducted, data on learning activities were collected and analyzed retrospectively. All data obtained during the design experiment phase were analyzed by comparing the initial conjectures and the Hypothetical Learning Trajectory (HLT) developed during the preliminary design with the actual results of the implemented learning trajectory based on the *Sagele* dance. This analysis aimed to assess the alignment between the designed learning trajectory and the students' responses during the learning process, as well as to understand how students constructed their understanding of integer operations through the culturally contextualized approach of the *Sagele* dance. This analysis involved comparing observations, field notes, and video recordings with the initial hypotheses developed during the preliminary design phase. The data were analyzed using a comparative approach, aligning students' observed 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.

## RESULTS AND DISCUSSION

### *Preliminary Design*

The preliminary design phase of this study was conducted through classroom observations and collaborative discussions between the researchers and teachers at SDN 1 Maria, Bima Regency, West Nusa Tenggara. The goal of this stage was to develop an initial framework for a culturally contextualized HLT focused on integer operations. The observations revealed that many students struggled to grasp the concept of integers, particularly in performing addition and subtraction. The existing instructional approach was primarily procedural and textbook-based, with limited incorporation of students' real-life experiences or local cultural values that are familiar and meaningful to them. To address this, researchers proposed integrating the *Sagele* dance—a traditional Bima dance—as a contextual media for learning. The dance's forward/backward and directional movements were aligned with positive/negative integers and arithmetic operations. Together with teachers, an initial HLT was designed to be flexible and open to iterative refinement based on classroom implementation and student responses.

The learning trajectory was designed in three stages: informal, referential, and formal, each aligned with specific learning activities that gradually guided students from cultural movement to abstract mathematical understanding. In the informal stage (Activity 1), students engaged in free-form *Sagele* dance movements to intuitively explore the ideas of direction and orientation—forward and backward steps representing positive and negative integers—supported by a handmade number line laid out on the floor. In the referential stage (Activity 2), students performed a structured and modified version of the *Sagele* dance based on agreed-upon rules. The choreography linked specific movements and body orientations to mathematical operations, helping students build a referential model of integer operations through kinaesthetic experience. In the formal stage (Activity 3), students transitioned from movement-based representations to abstract thinking by modelling and solving integer problems using a number line. This stage emphasized the symbolic representation of operations, reinforcing their earlier embodied experiences in formal mathematical terms.

### *Design Experiment*

The implementation of the learning trajectory using the *Sagele* dance proved to be an effective starting point for teaching integer operations. The trajectory consisted of three sequential activities, each designed to guide students from informal cultural experiences to formal mathematical understanding: informal, referential, and formal stage.

The design experiment consisted of two cycles. In the first cycle, the initial learning trajectory was tested, and observations were used to refine the activities. In the second cycle, the revised trajectory was implemented, yielding significant improvements in student engagement and comprehension. Evaluation results showed that students not only enjoyed the learning process but also demonstrated a

solid understanding of integer operations. The following section presents a detailed account of student learning outcomes in each activity across the two cycles.

*Activity 1: Identifying Integer Directions Through Sagele Dance with Free Movement*

In the activity of learning integer operations, the starting point chosen was the *Sagele* dance. The first step was to introduce the lesson, deliver its goals, and communicate them. Apperception was carried out to ensure students' initial knowledge regarding integers. The teacher then gave a brief explanation regarding the *Sagele* dance and students were asked to read the explanation of the *Sagele* dance using power point. The *Sagele* dance is a rice planting dance usually performed by the people of Maria Village, located in Wawo District, Bima Regency, West Nusa Tenggara Province. Women who perform the *Sagele* dance usually wear *Rimpu* from a typical Bima *Sarong/ Tembe Ngoli* (red circle) and traditional *Sambolo* (yellow circle), as illustrated in Figure 2. The *Sagele* dance is accompanied by peat musical instruments. However, in the activity of learning integer operations, the dance movements were accompanied by guitar musicians and a song modified by teachers and researchers to suit the material on integer operations.

**Figure 2.** Student wearing *Rimpu* and *Sambolo*

In Figure 2, the students are shown wearing traditional Bimanese costumes, with the boys donning *Sambolo*, a customary head covering, and the girls dressed in *Rimpu*, a traditional way of wrapping the sarong to cover the head and body modestly. At the beginning of the lesson, the teacher divided the class into two groups. One group took on the role of singers, while the other became the dancers. After each performance, the groups switched roles, allowing every student the opportunity to experience both aspects of the *Sagele* dance.

Before the activity commenced, the teacher carefully explained how the traditional *Sagele* dance would be used to represent integer operations. Students were instructed that when a positive integer appeared, they should perform the planting movement by stepping forward. Conversely, when

encountering a negative integer, the planting movement would require them to step backward. The direction they faced also held mathematical meaning: a left turn symbolized subtraction, while a right turn indicated addition. The atmosphere of the classroom became lively as the students embodied these mathematical ideas through movement. Through a series of questions and discussions, the teacher further guided the students in thinking critically about how numbers and operations could be physically represented through dance. This integration of cultural practices with mathematical concepts offered students an engaging and meaningful way to internalize the properties of integers. The teacher then facilitated a question-and-answer session to engage students in determining the placement of whole numbers during the *Sagele* dance activity. The following is a dialogue between the teacher and the students.

*T* : *"Do you still remember that if a whole number goes to the right, then what number does it get?"*
*S1* : *"It's getting bigger"*
*T* : *"What if you go to the left the number increases?"*
*S1* : *"It's getting smaller"*
*T* : *"Which is greater -11 or -20?"*
*S1* : *"-11"*

This dialogue demonstrates that students are beginning to internalize the concept of integer directionality through physical experience. By connecting movements in the *Sagele* dance with the mathematical idea of moving left or right on the number line, students were able to associate movement to the right with increasing values and movement to the left with decreasing values. The activity supported students in linking free body movement with numerical changes, helping them to intuitively grasp the relative magnitude of integers, especially negative numbers, before transitioning into more structured representations.

Before practicing the full choreography, the teacher encouraged the students to study the accompanying song. The song, adapted by the teacher and researchers using the *Mbojo* language and guitar accompaniment, was contextualized to align with the material on integers. The teacher then invited selected students to come forward and model the *Sagele* dance movements with free interpretations as a model for the rest of the class.

Reflection on the implementation of Activity 1 across Cycle 1 and Cycle 2 revealed several critical insights that informed the refinement of the learning trajectory. In the first cycle, while students engaged actively with the *Sagele* dance movements, some experienced difficulties in consistently associating the direction of movement (left/ right) with the corresponding mathematical operations (subtraction/addition). Although students understood the general idea that moving to the right corresponds to increasing values and moving to the left to decreasing values, confusion still occurred when these movements were linked explicitly to addition and subtraction tasks.

As a response, minor but important revisions were made prior to the second cycle. These included

refining the movement rules to more explicitly connect physical actions with numerical changes, enhancing instructional clarity, and developing additional supportive media such as culturally contextualized songs and number line visual aids. During the second cycle, these revisions proved effective: students demonstrated a more consistent understanding of the relationship between directionality and operations, and the role distribution among dancers, singers, and number line holders promoted clearer collaborative learning dynamics.

*Activity 2: Structured and Modified Sagele Dance Choreography for Modeling Integer Operations*

After completing Activity 1, Identifying integer directions through *Sagele* dance with free movement, in which students explored the directionality of integers through open-ended physical expression, the teacher proceeded to Activity 2, which featured more structured choreography. In this activity, the teacher invited students to come to the front of the class to perform the *Sagele* dance based on a modified routine and agreed-upon movement rules. Students in Group 1 were assigned as dancers, while Group 2 acted as singers. Each group consisted of six students, with four serving as dancers and two as number line holders. The established dance rules were as follows: (1) the dancer starts at position zero and faces to the right; (2) movements combine forward or backward steps with changes in direction (left or right); and (3) the dancer's final position represents the result of the integer operation. To support students' engagement and deepen their understanding of integer operations, the activity incorporated a rhythmic chant in the local *Mbojo* language. The beginning the activity, the teacher signalled the start of the performance by saying,

*T* : "*Ready… start." (The teacher gives the command to start the Sagele dance)*
*G2 (Singer)* : *"Tolu di tambah dua… tolu ditambah dua…. pila sih dambe?" ("Three plus two… three plus two… what's the answer?").*

Responding to the song, the dancers from Group 1 performed movements that corresponded to the integer operation "3 + 2", which involved stepping forward three times from zero, maintaining the same orientation, and then continuing with two additional forward steps to arrive at position 5. This performance exemplified how structured choreography could represent mathematical operations in a tangible and culturally contextualized manner. The movements performed by the students are illustrated in Figure 3, which represents the operation of adding positive integers through a sequence of forward steps aligned with the agreed rules.

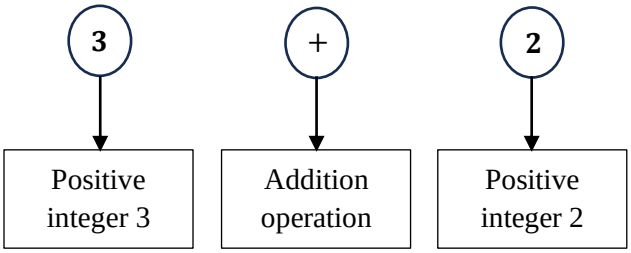


**Figure 3.** Representation of the operation of adding positive integers

In accordance with the agreed-upon rules, as depicted in Figure 3, the dancer began at position 0, facing to the right. The number 3, being a positive integer, instructed the dancer to move three steps forward, thereby reaching position 3. Subsequently, the addition operation signaled that the dancer should continue progressing in the same direction. Following this, the dancer advanced two more steps, corresponding to the addition of positive integer 2. Ultimately, the dancer arrived at position 5, demonstrating that the sum of 3 and 2 is 5. Upon the completion of the movement sequence, the teacher asked all students to articulate the result of the addition operation referenced in the song performed by Group 2.

To reinforce students' understanding of integer addition, the teacher invited representatives from Group 1 to demonstrate the *Sagele* dance based on the agreed rules. Students performed the sequence of movements while referring to the number line laid out in front of the class. This activity allowed students to visualize the mathematical operation through coordinated body movements, making abstract concepts more tangible and meaningful.


**Figure 4.** Demonstration of the *Sagele* dance related to the operation of adding positive integers

Furthermore, Figure 4 shows students demonstrating the *Sagele* dance while enacting the process of adding positive integers. In the left panel, students are seen preparing at position 0 before making forward movements according to the given numbers. In the right panel, students successfully reach the final position at number 5 after sequentially performing the dance steps that represent the operation 3 + 2. This physical representation supported students' understanding of integer addition by connecting symbolic operations with embodied movements.

The next activity was to demonstrate the operation of adding negative and positive integers, as illustrated in Figure 5. The teacher then asked group 2 to come forward as dancers and group 1 as singers.

| | | |
|---|---|---|
| *T* | : | *"Groups 1 and 2 are ready to start" (gives the command to start the Sagele dance)* |
| *G1 (Singer)* | : | *"Negatif tolu di tambah dua, negatif tolu ditambah dua, pila sih dambe?". (Negative three plus two, negative three plus two, what is the result?)* |

Group 2 demonstrated the *Sagele* dance according to group 1's song in the form of operations on positive integers as follows:

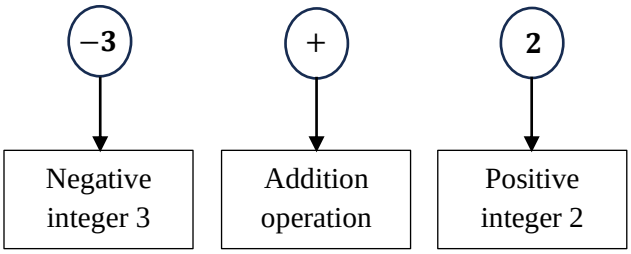


**Figure 5.** Representation of the operation of adding negative and positive numbers

Figure 5 shows the rules, first, the dancer's position is at number 0 and facing to the right, -3 is a negative number so the dancer's movement back 3 steps is at the number -3 position. Second, there was an addition operation, thus, the dancer's position remained in the number -3 position and remained facing right, then continued with a two-step forward movement. The dancer's final position was -1, so -3 + 2 = -1.

In the subsequent stage of the lesson, students were challenged to demonstrate a more complex operation involving both negative and positive integers using the *Sagele* dance. Through this activity, students were expected to internalize the meaning of negative direction (backward movement) and positive direction (forward movement) on the number line. The dance movements were carefully structured to align with the mathematical operations being performed. The teacher asked all students to state the results of the operation of adding negative and positive integers mentioned through group 1 singing, as illustrated in Figure 6.


**Figure 6.** Demonstration of *Sagele* dance related to the operation of adding negative and positive integers

Figure 6 showed the demonstration of students first moved backward to represent the addition of a negative integer and then moved forward to represent the addition of a positive integer. By physically enacting the direction and magnitude of the integers, students could better grasp the concept of integer addition, including how positive and negative values interact on the number line. This embodied learning approach supported deeper conceptual understanding and engagement with abstract mathematical ideas.

Building upon their understanding of addition involving negative and positive integers**,** the next activity required students to demonstrate the operation of subtracting negative and positive integers. In this stage, the teacher invited group 1 to come forward as dancers and group 2 as singers.

*T* : *"Groups 1 and 2 are ready to start" (gives the command to start the Sagele dance)*
*G2 (Singer)* : *"Negatif tolu dikurangi dua, negatif tolu dikurangi dua, pila sih dambe?" ("Negative three minus two, negative three minus two, what's the answer?")*

Group 1 then demonstrated the *Sagele* dance according to group 2's song, modeling the subtraction of negative and positive integers as follows.

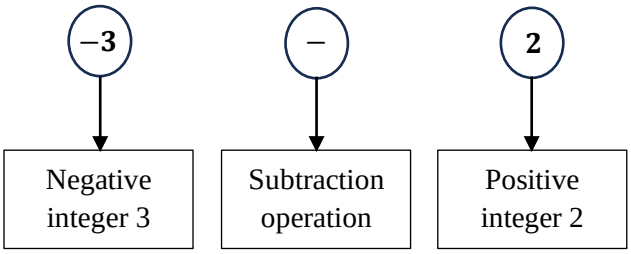


**Figure 7.** Representation of the subtraction operation of negative integers

As shown in Figure 7, the demonstration adhered to a set of established rules designed to connect bodily movement with mathematical operations. Initially, the dancer positioned themselves at point 0 on the number line, facing to the right. Since the integer -3 represents a negative value, the dancer moved three steps backward, landing at position -3. Given that the operation was subtraction, the dancer then maintained their position at -3 but rotated to face the opposite direction (to the left), symbolizing a change in orientation due to the subtraction process. Subsequently, the dancer moved two steps forward in the new facing direction, ultimately arriving at position -5. Through this movement, the students embodied and visualized the calculation -3 – 2 = -5. To reinforce the connection between the dance movements and the mathematical operation, the teacher prompted all students to verbally state the result of the subtraction operation that had been introduced through Group 2's singing.

During the first cycle of Activity 2, students engaged in performing choreographed routines designed to model specific integer operations, such as the addition and subtraction of positive and negative integers. Although the structured choreography effectively organized the sequence of movements, several students exhibited difficulties in determining when to maintain or change their facing direction, particularly during subtraction operations. Some students hesitated or appeared uncertain when instructed to rotate their orientation, indicating that their understanding of the operational rules was still emerging. At this stage, students had begun to establish connections between symbolic mathematical operations and embodied actions; however, their procedural fluency in translating these operations into coordinated movements remained limited.

In the second cycle, improvements were evident following the refinement of instructional guidance, which emphasized maintaining the initial orientation during addition and rotating to the opposite direction during subtraction. With clearer operational cues, students performed the routines

with greater fluency and confidence. They accurately modelled the addition of positive integers through consistent forward movements, represented the addition of a negative and a positive integer by moving backward and then forward, and demonstrated subtraction involving negative numbers by correctly changing facing direction before proceeding with the appropriate steps. Cognitively, students achieved a level of operational abstraction, successfully integrating symbolic, verbal, and physical representations of integer operations. Furthermore, their ability to verbally articulate the results of their movements improved significantly, indicating a deeper and more coherent conceptual understanding of integer operations.

*Activity 3: Modeling Jumps of Numbers Forward or Backward Through a Number Line*

After completing Activity 1 and Activity 2, the teacher assigned Activity 3 to further strengthen students' understanding of integer operations. In this activity, students were asked to solve problems involving integer addition and subtraction by modelling jumps forward and backward on a number line. The integration of number line modelling successfully guided students from the concrete experience of the *Sagele* dance to the formal representation of integer operations. A critical achievement in Activity 3 was the teacher's success in scaffolding students' transition from informal, movement-based understanding to formal mathematical procedures. Students demonstrated their ability to represent the addition of positive and negative numbers through directed jumps on the number line, providing a clear link between embodied learning experiences and symbolic mathematical operations.

These three activities are a process to take students from informal to formal mathematics (Simamora & Saragih, 2018). At an informal level, students discover and understand that positive integers are a forward movement, negative integers are a backward movement, addition operations are a movement facing the right, and subtraction operations are a movement facing the left. At the referential level, *Sagele* dance movements are modified through agreed rules that: 1) the dancer's starting position is at number 0 and facing to the right, 2) *Sagele* dance movements combine forward or backward movements with movements facing left or right, and 3) the final position of the dancer is the result.

This is a student strategy to make it easier for students to find which concepts are included in integers and which are included in addition or subtraction operations. At the general formal level, students are instructed that jumping forwards or backwards in numbers illustrates integer operations. After achieving several basic concepts of integer operations, students are able to solve problems at a formal level using their knowledge and experience at the situational, referential, and general levels (Santri & Somakim, 2019).

Figure 8 illustrates an example of a student's work produced during the evaluation phase. In this example, the use of number line jumps—both forward and backward—successfully facilitated the formalization of procedures for adding and subtracting positive and negative integers.

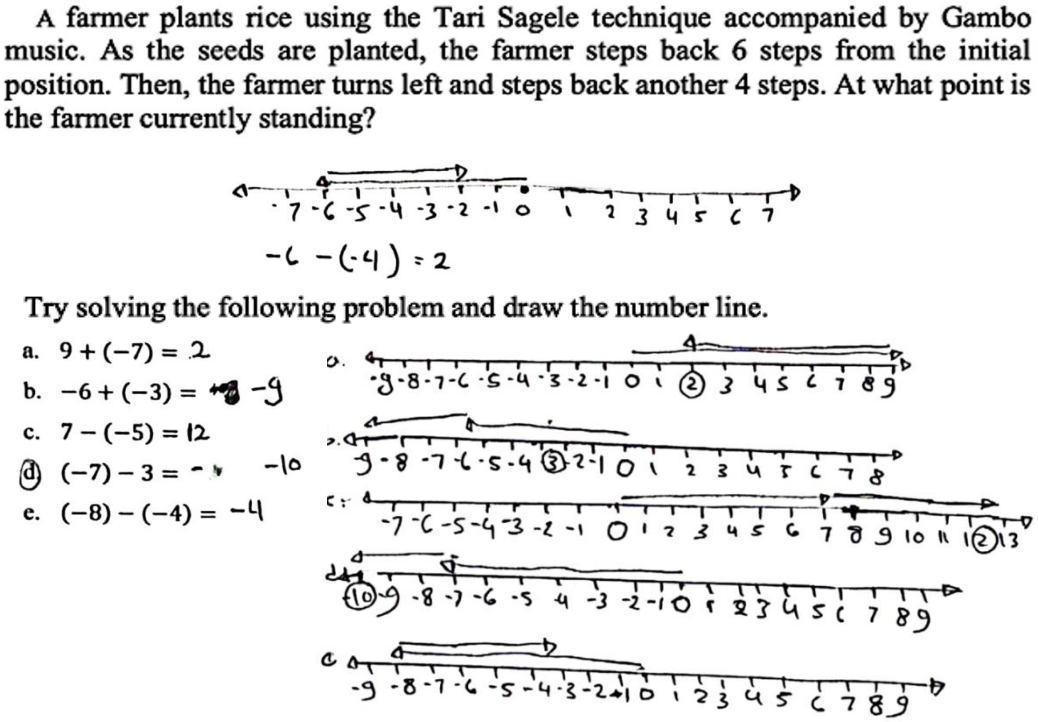


**Figure 8.** Students' work

Figure 8 illustrates students' activities during the formal stage of learning integer operations. In this activity, students were tasked with solving a word problem involving a farmer planting rice using the Tari *Sagele* technique. The farmer steps back six steps from the starting point, then turns around and steps back another four steps. This situation is modelled by the operation −6−(−4) and visualized through jumps on a number line, resulting in a final answer of 2. This visualization helped students understand that subtracting a negative number is equivalent to moving in the positive direction on the number line.

Subsequently, students worked on additional exercises involving the addition and subtraction of integers, representing each operation with jumps on a number line. The students' work demonstrated their ability to connect symbolic operations with visual representations: forward jumps for the addition of positive numbers and backward jumps for the addition of negative numbers. They also successfully understood that subtracting a negative number results in movement to the right, while subtracting a positive number results in movement to the left. Through this activity, it is evident that students progressed from situational understanding to referential reasoning and eventually to formal problem-solving, drawing upon their embodied and visual learning experiences.

***Retrospective Analysis***

The retrospective analysis was conducted after the implementation of the design experiment as a reflective process to understand the learning dynamics that emerged and to further refine the learning trajectory. In this phase, the researchers compared the Actual Learning Trajectory (ALT) experienced

by students with the Hypothetical Learning Trajectory (HLT) developed during the preliminary design phase. This comparison focused on assessing students' conceptual understanding of integer operations, their problem-solving strategies, and their ability to transition from informal to formal stages of mathematical reasoning (Hidayatullah, 2023).

Data collection was carried out through triangulation involving multiple sources: video recordings, field notes, photographic documentation, student worksheets, and response questionnaires. The analysis was structured around the phases of the learning trajectory: informal, referential, and formal. For example, in an early activity, the teacher asked, "What happens when a number moves to the right?" and a student responded, "It gets bigger." When asked, "Which is greater, -11 or -20?" the student answered, "-11." These responses reflected an emerging understanding of negative numbers and relative magnitude, suggesting that kinesthetic experiences embedded in the Sagele dance facilitated students' conceptual development in integer operations.

During the first cycle, several students struggled to associate movement direction (left/right) with the corresponding mathematical operations (subtraction/addition). This finding prompted revisions to the initial HLT, including clarification of movement rules, enhancement of instructional strategies, and the incorporation of culturally contextualized support materials such as local songs and number line posters. These refinements were implemented in the second cycle, which involved a different class at the same school, consisting of 28 students with varied levels of initial mathematical ability.

The second implementation also emphasized collaborative engagement through clear role assignments (e.g., dancers, singers, number line holders). Figure 9 presents the student responses to the revised learning activities.

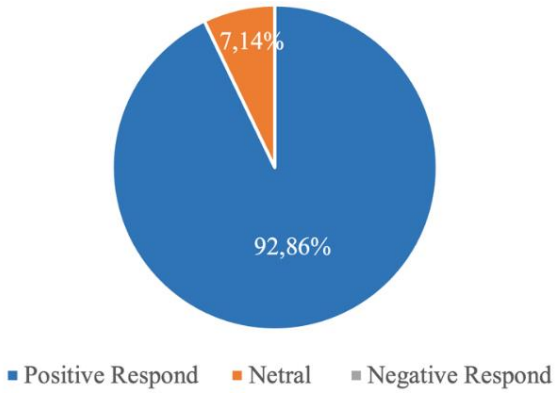


**Figure 9.** The student responses

The questionnaire results showed that 92.86% of the 28 participating students responded positively to the learning experience, while 7.14% were neutral. These responses suggest that most students benefited from the culturally embedded and participatory instructional approach. Their improved engagement and understanding can be attributed to the revised strategies, including the use

of visual supports, structured role distribution, and meaningful kinaesthetic experiences that reinforced mathematical concepts.

Building on these responses, further implementation data confirmed students' conceptual growth across the learning trajectory. A total of 89.3% demonstrated a sound understanding of positive and negative integers through the modified *Sagele* dance-based activities. Additionally, 85.7% effectively modelled integer operations using choreographed movement rules, and 82.1% successfully solved formal mathematical problems using number lines, articulating their reasoning clearly. These results underscore the role of local cultural practices—such as the *Sagele* dance—in bridging informal experiences and formal mathematical representations. The distribution of students' progression across learning stages is shown in Figure 10.

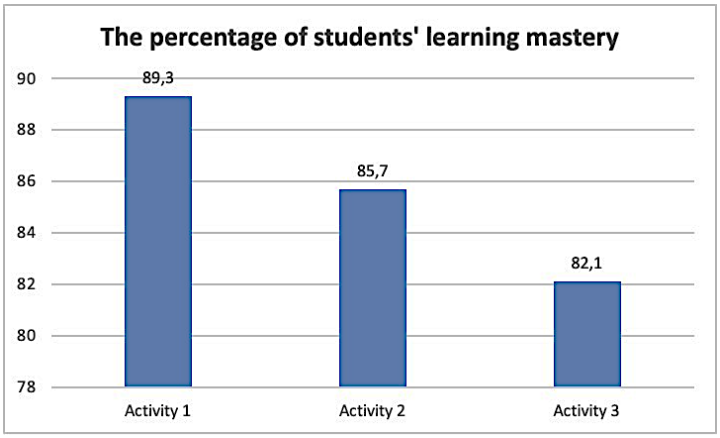


**Figure 10.** Distribution of student learning trajectory stages in integer operation

As shown in Figure 10, there is a slight yet consistent decrease in the percentage of students achieving mastery as activities progressed in complexity—from 89.3% in Activity 1 to 85.7% in Activity 2, and 82.1% in Activity 3. This pattern likely reflects the increasing cognitive demands associated with transitioning from embodied learning to formal mathematical abstraction. Nevertheless, the high levels of performance across all stages affirm the effectiveness of the learning trajectory in supporting students' mathematical development while fostering cultural identity and collaborative learning practices.

The findings of this study indicate that integrating local cultural elements into mathematics instruction—particularly through the traditional *Sagele* dance—significantly enhances students' understanding of integer operations. This culturally grounded approach effectively guided students from informal experiences toward formal mathematical understanding through a structured progression, consisting of the informal, referential, and formal stages as conceptualized by Gravemeijer (2004) in the Hypothetical Learning Trajectory (HLT) framework.

In the informal stage, the use of forward and backward movements, as well as directional changes within the *Sagele* dance, provided kinesthetic experiences that helped students develop an initial

conceptualization of positive and negative integers. These findings align with those of Muslimin et al. (2020), who demonstrated that a contextual approach rooted in Islamic cultural practices strengthened students' understanding of integers by situating learning within meaningful, everyday experiences. Furthermore, the incorporation of cultural context allowed students to connect their prior experiences with new mathematical concepts, fostering meaningful learning (Retnawati et al., 2018; Verawati, 2024).

During the referential stage, when dance movements were formalized and directly linked to addition and subtraction operations, students began to generalize these movements into mathematical models. This parallels the work of Risdiyanti et al. (2019), who used the traditional game Kubuk Manuk to facilitate students' understanding of social arithmetic operations. Both studies underscore the role of cultural contexts as effective bridges between concrete experiences and symbolic mathematical representations.

In the formal stage, students demonstrated their ability to solve integer problems using number line representations. This outcome indicates not only enhanced engagement but also successful conceptual transitions to more abstract reasoning. These results are consistent with those of Santri and Somakim (2019), who found that integrating local experiential contexts into mathematics learning supports students' development of formal thinking through meaningful visual models. Moreover, this study found that group-based activities, in which students assumed roles as dancers and singers, fostered constructive social interaction. This finding reinforces Vygotsky's sociocultural theory, emphasizing the importance of social interaction in the internalization of concepts. These collaborative activities not only strengthened conceptual understanding but also promoted cooperation and cultural appreciation among students.

The success of this approach is further supported by quantitative data, which revealed that over 80% of students achieved a sound understanding of integer operations by the final phase of instruction. This represents a significant improvement from the initial stage and echoes findings by Nuraida and Amam (2019), who demonstrated that integrating the Barathayudha folk tale into number pattern lessons enhanced both student motivation and conceptual comprehension.

Overall, this study reinforces the argument that integrating local culture into mathematics education is not only cognitively beneficial but also affectively meaningful. The use of the *Sagele* dance as a contextual learning tool not only facilitates the comprehension of abstract mathematical concepts but also strengthens students' cultural identity and local values. Such integration makes mathematics instruction more inclusive, relevant, and transformative, while also contributing to the development of culturally responsive mathematical literacy.

The utilization of the *Sagele* dance to teach whole number operations resulted in a positive experience for the students, as evidenced by the evaluation questions' results, which demonstrated a solid understanding of the concept (Andriani et al, 2020). To develop students' knowledge to a higher level it is necessary to involve direct meaningful learning activities (Hastuti et al., 2020; Sutarto et al.,

2022). This research can be a reference source in developing a learning trajectory for learning the operations of adding and subtracting integers using local cultural contexts in the form of traditional dances. In addition, previous research has proven that learning trajectories that involve local culture can make it easier for students to build mathematical concepts. This includes research on the trajectory of learning number patterns using the war stories Barathayudha and Uno Staco (Nuraida & Amam, 2019), the trajectory of learning social arithmetic using the traditional game Kubuk Manuk (Risdiyanti et al., 2019), the trajectory of learning entrepreneurial arithmetic material using context traditional markets (Wibawa et al., 2022).

## CONCLUSION

The concept of integer operations can be understood, applied, and reasoned by students through the integration of local cultural contexts, such as traditional dance. This study developed and implemented a learning trajectory for integer operations using the context of the *Sagele* dance, a traditional dance from Bima, West Nusa Tenggara. he developed learning trajectory consists of three sequential activities: Activity 1 (Identifying integer directions through *Sagele* dance with free movement), where students explored the directional meaning of integers through open-ended physical movements; Activity 2 (Structured and Modified *Sagele* Dance Choreography for Modeling Integer Operations), where students modeled addition and subtraction of integers through choreographed dance movements based on agreed-upon rules; and Activity 3 (Modelling integer operation using a number line), where students formalized their understanding by representing the operations on a number line. Through these activities, students transitioned from informal kinesthetic experiences to formal symbolic representations of integer operations, demonstrating the effectiveness of culturally contextualized learning trajectories in mathematics education.

This study has several limitations, namely: it was conducted in a single location focusing solely on the *Sagele* dance, which limits the generalizability of the findings to other geographical areas or different tourism contexts. Additionally, the sample size is relatively small, which may affect the robustness of the conclusions drawn. This research primarily employs qualitative methods, and although these methods provide valuable insights into student cognition, a more comprehensive approach that includes quantitative measures would enhance the validity of the findings. This research contributes to the body of literature on innovative teaching methods in mathematics by providing a replicable model for incorporating cultural practices into learning trajectories. Future research should explore broader applications of this approach, addressing challenges in curriculum integration and teacher training to support the sustainable use of ethnomathematics in formal education.

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## DECLARATIONS

| | | |
|---|---|---|
| Author Contribution | : | IDH : Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, and Writing - Original Draft<br>YM : Investigation<br>S : Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, and Writing - Original Draft |
| Funding Statement | : | This research was funded by Universitas Muhammadiyah Mataram through the Professorship Acceleration Grant Scheme. |
| Conflict of Interest | : | The authors declare no conflict of interest. |
| Additional Information | : | Additional information is available for this paper. |

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