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Learning trajectory of adding and subtracting integers through the Indonesian kempreng game

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Abstract

Traditional games can be used as learning designs to understand mathematical concepts. However, learning designs that can stimulate the understanding of adding and subtracting integers for primary students have not been found by the learning trajectory (LT). This research aims to design an LT through traditional games to help construct students' understanding and mathematical concepts through various activities that have been developed. Hypothetical learning trajectory (HLT) predicts how primary students' thinking develops in learning activities. This study uses design research with stages, namely preliminary design, teaching experiment and retrospective analysis. In this study, the realistic mathematics education approach was used to map student activities into modes of, for, and formal. The results showed that LT using kempreng as a context could stimulate students' thinking in understanding the mathematical concepts of adding and subtracting integers. Based on the results of research that has been carried out in this study, it can be seen that the impact on the research design also occurs on teachers. Learning becomes a student center, the teacher as a facilitator. All activities designed on the LT are carried out in groups with a discussion system.

Keywords: design research; kempreng game; learning trajectory.

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Introduction

Primary students still have difficulty understanding mathematical concepts (Benavides-Varela et al., 2020; Dündar et al., 2011; Nugraha et al., 2020; Nyborg et al., 2022). The form of difficulty faced by students is their inability to explain the relationship and application of mathematical concepts (Ende et al., 2022). Many factors underlie primary students' difficulty understanding mathematical concepts, especially in the addition and subtraction of integers. One of the factors is teacher-centered learning, so students become passive and learning becomes meaningless (Hubbard & Livy, 2021; Jalani & Sern, 2015; Wahjuni, 2012). In addition, teacher-centered learning has negative consequences for students because students accept concepts without any direct activity (Lestari et al., 2021). To turn learning into a student center, it must stimulate students to work together in solving problems (Maryati & Charitas Indra Prahmana, 2021; Pathuddin & Nawawi, 2021; Yu et al., 2022).

Student center learning will make students have a sense of responsibility to solve a problem because they have to seek solutions from a predetermined topic actively. In finding a solution, the teacher's role as a facilitator is needed to explore primary students' knowledge (Osmanović Zajić et al., 2021). Efforts that can be made are connecting the topic of mathematics with their culture or daily life. Ethnomathematics connects mathematics within a culture (Pratiwi & Pujiastuti, 2020).

Ethnomathematics can facilitate primary students to be able to construct mathematical concepts from the initial knowledge they already have (Mania, 2021). The use of ethnomathematics as a basis for learning can be used to improve the understanding of primary students in finding mathematical concepts (Cimen, 2014), including arithmetic operations (Elly Susanti, 2021). One form of ethnomathematics closely related to primary students' daily lives is traditional games. Traditional games related to mathematics, especially addition and subtraction material, are traditional kempreng games (Susanti, 2020). This game comes from the city of Mojokerto, East Java, Indonesia.

In previous study, the kempreng game was not designed to construct mathematical concepts for primary schools meaningfully. Besides that. the media used is only single without any variations (Susanti, 2020). Meanwhile, to design a learning trajectory (LT), a Hypothetical Learning Trajectory (HLT) is needed. Previous research on the development of LT or HLT designs in a cultural context impacts students' deep mathematical understanding. Study by (Handayani et al., 2015) found that HLT in research design is used as a description of the flow of learning material to be used in research. Designing activities using contexts that can attract students' attention will raise their motivation to learn mathematics. The researchers' results prove that the knowledge and ability of students' to understand the research context has increased.

Research focusing on LT design requires mapping learning activities in the form of mode of, mode for, and formal (Nuraida & Amam, 2019). This activity mapping variation is oriented to the realistic mathematics education (RME) approach to forming concrete into formal forms (Ilma et al., 2020). Thus, designing HLT activities by mapping them into modes of mode, for mode and formal mode, is needed to produce adequate and appropriate LT in the kempreng game by processing information for primary students. To overcome the research gap between the needs and the facts of the problem, this research aims to produce an LT design on the addition and subtraction of integers using the traditional kempreng game, which is integrated in activity mode for and formal for primary students.

Methods

This research method uses research design to produce LT through HLT, which contains a series of continuous activities to achieve a goal (Bakker et al, 2014). The learning activities are divided into three sessions: mode of, mode for, and formal. The participants were 29 grade IV primary school students in Mojokerto, East Java. The research instrument uses a worksheet. Data collection techniques were carried out by observation, tests, interviews and documentation (videos and photos). Interviews were conducted when the research was taking place, namely open interviews so that researchers got direct responses from students. The HLT design and development process in this study used three stages, namely: preliminary design, teaching experiment, and retrospective analysis (Ilma & Putri, 2012).

Preliminary design is designing a learning activity from the concrete to something more abstract. Designing an activity design cannot be separated from a learning trajectory, which contains learning materials and representations. Furthermore, the learning trajectory used in the mathematical concept of the topic of number operations in learning addition and subtraction of integers was developed so that it is worthy of being a local instruction theory (LIT). The design on the learning trajectory concept was developed on HLT, which is useful for anticipating the alleged answers of students in the learning activities that will be carried out. This assumption predicts students' thinking that develops in learning activities. The series of HLT activities are divided into three stages: learning objectives, learning activities, and the basic concepts of adding and subtracting integers (Gurbuz & Ozdemir, 2020).

Teaching Experiment, namely implementing the stages that have been designed in HLT by dividing into several small groups, which were chosen intentionally. The goal is to see to what extent students can explore the learning series that have been designed. In comparison, the observations were made during the learning process at the stage of learning activities. The teacher notes how and what is done from the beginning - to the end of the study.

Retrospective analysis is data obtained, collected, and analyzed after previously designed learning activities. The learning trajectory that was developed in the initial design will be compared from the beginning - to the end of the learning activities that have been carried out. The general aim at this stage is to establish LIT theory.

Results

This section reviews the process of producing LT at the preliminary design, teaching experiment, and retrospective analysis stages. Each of these stages is designed for the Kempreng game HLT activity on the material of adding and subtracting integers. Then each HLT activity is mapped into the RME approach in the form of mode of, mode for, and formal.

Preliminary Design

At this stage, the HLT was designed using three activity sessions. The first activity begins with a concrete form (mode of), the second activity in a semi-concrete form (mode for) and the third activity in an abstract form (formal). The LT is used as an initial stage to design the learning concept that will be passed by the primary student, as shown in Figure 1.

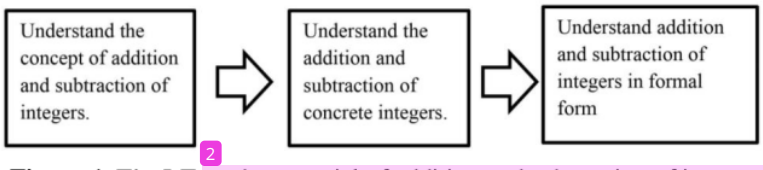

Figure 1. The LT on the material of addition and subtraction of integers

The HLT design connects the learning stages, learning activities, and the basic concepts of adding and subtracting integers. Then the HLT design is mapped into the mode of activity, mode for, and formal knowledge. The results of the HLT design are presented in Figure 2.

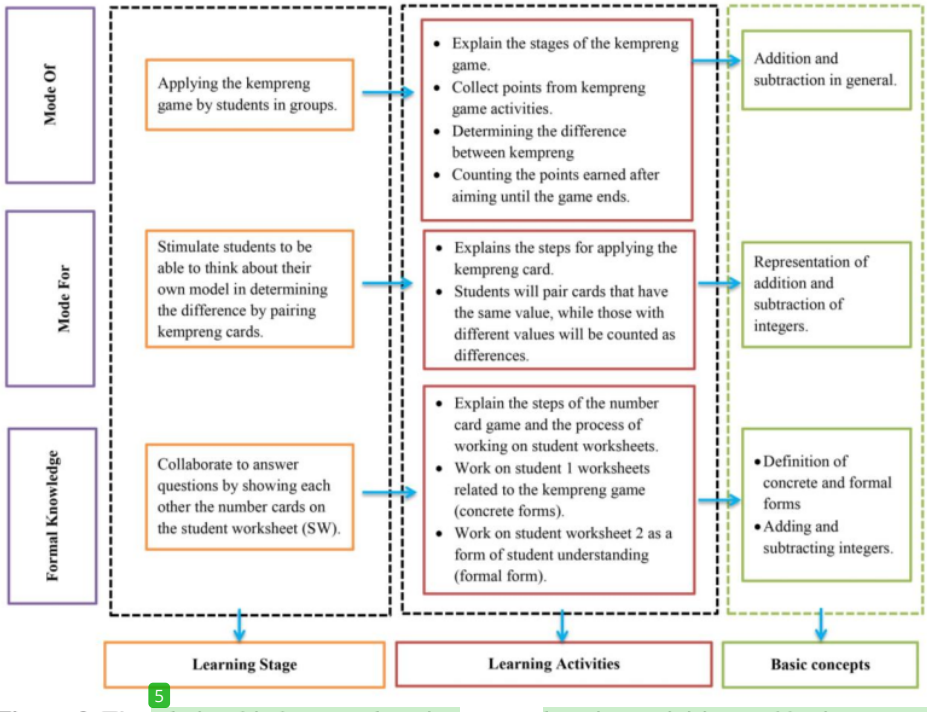

Figure 2. The relationship between learning stages, learning activities, and basic concepts

Teaching Experiment dan Retrospective Analysis

In this section, the teaching experiment and retrospective analysis stages are presented simultaneously. The presentation is carried out according to the learning stage, which includes activities and basic concepts designed in mode of, mode for and formal knowledge. This learning stage is divided into understanding the concept of the kempreng game, determining the difference and negative numbers using the kempreng card, and writing the results of the number cards on the worksheet.

Understanding the Concept of the Kempreng Game

This activity aims to foster students' understanding of the concept of arithmetic operations on the addition and subtraction of integers. In this context, the use of RME helps increase students' understanding of the mathematical concepts of primary schools. Learning activities are carried out in groups consisting of 5 students in each group and each stage of the game is

carried out by different students. In addition, as a form of evaluation in this activity students will calculate, mention the difference in kempreng needed and determine the winner.

In the first activity, students were introduced to the kempreng game, as an early opening for learning. The teacher starts the lesson by distributing a reading to the students. Then ask the students about their knowledge and experience with the traditional game of kempreng. The teacher provides an opportunity for students to convey their experiences if they have ever played kempreng (bottle cap). After that, the teacher asked the students to read the material studied in the kempreng game, namely the addition and subtraction of integers in the student's book. Next, the teacher asks students to follow the steps of the kempreng game explained. The game's duration depends on the shooting process that the student takes. After playing the kempreng game, students will count the points that have been obtained during the game and mention the difference between the kempreng. Finally, the students said who the winners were in this first activity and what they learned in this activity. Students are allowed to ask questions about the kempreng game and the material that has been implemented. In this case, the data is obtained from student activities directly.

Students apply the kempreng game, which one student in each group represents. The way to do this game is by aiming. Then, the students counted the points they got during the shoot from beginning to end, as in Figure 3. The researchers conducted questions and answers with students about the difference and stimulated students to find ways to determine the difference (Shutenko et al., 2021). This is because they will get a different number of kempreng. The winner in the second activity will get more kempreng. In addition, researchers provide opportunities for students to ask questions or give feedback on activities in this activity (Chevalier et al., 2022). The analysis in the mode consists of activities, predictions for students, and teacher responses in answering questions given by students in Table 1.

(a) (b)

Figure 3. (a) Students apply the kempreng game (b) Counting points

Tabel 1. Aktivitas Mode of

Activity Mode of → Descriptor (1) The teacher asked the students about their knowledge and experience with the kempreng game.	
Student Predictions	- Knowing or having knowledge and experience of playing kempreng. - Does not have the knowledge and experience of playing kempreng.
Teacher's Response	Stimulate students to answer questions about the kempreng game.
Activity Mode of → Descriptor (2) The teacher pairs and mentions the difference during the kempreng game.	
Student Predictions	Pairing and mentioning the difference when the kempreng game takes place correctly or not
Teacher's Response	- Guiding students to pair and mention the difference during the

	kempreng game - Providing verbal appreciation of student work.

Based on the results of the analysis in the first session of the mode of activity, students can understand the basic mathematical concepts of arithmetic operations. Students were very enthusiastic in carrying out the first activity and were also active in asking questions during the activity. These results indicate that explaining the material in a concrete form is easier for students to understand.

Determining Difference and Negative Numbers Using the Kempreng Card

The second activity aims to encourage students to understand negative integers and the difference in the addition and subtraction of integers through the kempreng game. With the hope of being able to answer questions in the student book regarding the reduction of positive integers. As well as linking this chapter's math material into a kempreng game through kempreng cards (Baglama et al., 2017).

In this second activity, students listen to the teacher's explanation of how to use the kempreng card. Students must also understand the difference in material / negative integers in the student book before the for mode starts. After that, they were implementing the kempreng card to find out the difference from the kempreng card game that had been done. Finally, the results of the card game are shown and calculated. Then evaluated in the form of a question and answer discussion between teachers and students. The data was obtained when the activity had taken place in the second session.

In the second activity, the researcher explained the steps for implementing the kempreng card. This card game is played with each group by two players. Before being dealt, the cards are shuffled first, then divided. Each player gets 6 kempreng cards because the total number of cards is 12. If the representation of the kempreng is the same, it is not counted as a difference. However, "if the representation of the kempreng is different, it is called a difference. For example, the card shown with the kempreng image is one and one, so it is not different. If there are two and three kempreng pictures shown, it is called a difference", see Figure 4. As an evaluation of activity two, each student shows the results of the kempreng game he has done. The analysis in the for mode consists of activities, predictions of student responses, and teacher responses in answering questions given by students in Table 2.

(a) (b)

Figure 4. (a) Implementing the kempreng card (b) The results of the kempreng card game

Tabel 2. Aktivitas Mode for

Activity Mode for → Descriptor (1) Students observe and understand negative integers or differences.	
Student Predictions	Understanding or not understanding negative integers.
Teacher's Response	Facilitating students to understand negative integers or differences.
Activity Mode for → Descriptor (2) Students implement the kempreng card game and show the results or differences in the kempreng cards that have been applied.	
Student Predictions	Able or not able to show the results of the kempreng card that has been applied.
Teacher's Response	- Explaining and showing the results of the kempreng card game. - Giving verbal appreciation to students.

The results of the analysis in the second session were that they were able to understand the basic mathematical concepts of difference which could be seen from the results shown by the students. The kempreng card game is a representation of the kempreng form. In this case, learning is still done using concrete objects.

Writing Results from Number Cards on a Worksheet

This third activity aims to encourage students' understanding of defining addition and subtraction of integers when they know that integers consist of 2 parts, namely, positive integers and negative integers. In addition, to explain to students through number card games, they are continued by working on worksheets. With the hope of being able to explain the addition and subtraction of integers in a formal form through the question sheet that has been made.

In the third activity, students collaborate with opposing groups to answer the worksheets that have been given. As an evaluation of students' understanding of the material for adding and subtracting integers through the kempreng game, a second worksheet on the material for adding and subtracting integers was given. Finally, after students work on the questions that have been given, the teacher will discuss to discuss the problem.

In the third activity, students will play number cards. To play number cards, students must collaborate with the opposing group or exchange the cards they get to answer the questions on the worksheet. There are 10 number cards in which there are different values. As a form of evaluation, three students will work on a worksheet in a formal form (Forgasz & Markovits, 2018), as in Figure 5. Analysis of formal knowledge consists of activities, predictions of student responses, and teacher responses in answering questions given by students in Table 3.

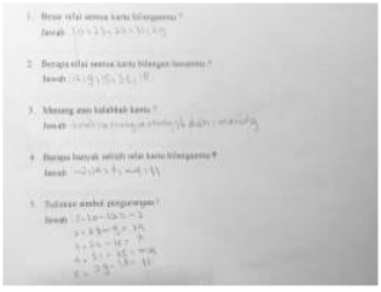

Figure 5. Results of worksheets

Tabel 3. Formal Knowledge Activities

Formal Knowledge Activities → Descriptors (1) **Let's think 1** Students define the addition and subtraction of integers.	
Student Predictions	Defining the addition and subtraction of integers when they know that integers consist of 2 positive and negative integers.
Teacher's Response	Exploring students' difficulties when defining addition and subtraction of integers in the activities that have been carried out.
Formal Knowledge Activities → Descriptors (2) **Let's think 2** Students work together on a worksheet using number cards.	
Student Predictions	Able or not able to work on student worksheets using number cards.
Teacher's Response	Guiding students in using number cards and answering worksheets.
Formal Knowledge Activities → Descriptors (3) **Let's think 3** Students write the results of understanding in a formal form through the second worksheet.	
Student Predictions	Able or not able to write the understanding results in a formal form.
Teacher's Response	Exploring students' difficulties in answering questions in a formal form.
Formal Knowledge Activities → Descriptors (4) **Let's think 4** Students explain the learning experiences they get during the kempreng game.	
Student Predictions	Can or cannot express feelings and interests during the kempreng game.
Teacher's Response	Stimulate students to be able to explain the kempreng game as a form of student evaluation.

Based on the analysis results in the third session, they were able to understand the basic mathematical concepts of arithmetic operations. Using number cards as learning media to answer questions on the worksheet. This activity invites students to think from semi-concrete to formal.

The results of the design experiment that have been designed show that this context aims to know the extent to which students understand the concept of counting integers from the designed learning trajectory (Stanković et al., 2018), like the one in Figure 6 the iceberg. The presentation in each learning activity is depicted on the iceberg, which includes the learning stages starting from concrete and semi-concrete to formal things. The strategies and models used are self-discovery, group discussions, and direct question-and-answer activities to measure student understanding. These results have differences from previous studies. In addition, this research integrates everyday cultural learning through a Realistic Mathematics Education approach (Deniz & Kurt, 2022; Sumirattana et al., 2017).

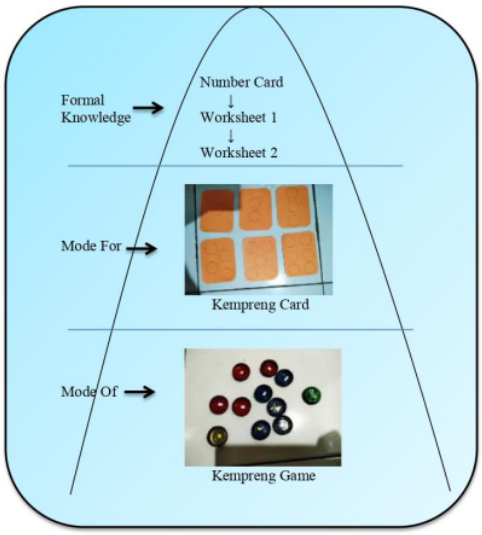

Figure 6. The design of the learning iceberg for addition and subtraction of integers.

According to their characteristics, several activities have been carried out by students as a form of increasing understanding of mathematical concepts in integer arithmetic operations. The first characteristic is using kempreng to explore students' thinking because the first activity uses concrete objects. After that, the teacher helps students by stimulating them to be able to think critically and evaluate the activities that have taken place with question and answer activities. The mode of activity is applied according to the characteristics of the RME approach (Nugraheni & Marsigit, 2021).

In the activity mode for using kempreng cards as a medium to stimulate students' understanding of mathematical concepts from the previous session with the form of representation of kempreng. After that, students will pair cards that have the same number. This is one way of teaching the difference in the form of representation (Mainali, 2021). In addition, the use of card media is often used in students' daily lives (Singh et al., 2021; Turkay et al., 2012).

Finally, in formal knowledge activities, number cards are used to shape students' thinking so that they are able to think formally. Students are guided from concrete thinking to abstract thinking (Özdemir et al., 2021). In addition, students will cooperate with opposing groups in completing the game in the third activity. In this case students will learn many things about the importance of cooperation in solving a problem (Stovner & Klette, 2022).

Using the context of the kempreng game in this study, it is one of the activities to explore culture close to students' daily lives, according to the basic concepts of primary school mathematics. The use of traditional games in this activity to preserve the culture that existed in the last decade has been abandoned. Some kinds of literature also make mathematics learning designs with an RME approach such as the set of numbers using the Mahabharata story (Risdiyanti & Prahmana, 2021), integer subtraction using the traditional game of congklak (Ilma & Putri, 2012), and also adding and subtracting numbers using rubber bands (Edo et al., 2015).

Conclusion

Based on the research results that have been described. It can be concluded that kempreng as a context has an essential role in designing LT in learning addition and subtraction of integers. The designed LT will become a LIT, so it requires HLT to design learning activities. The HLT design consists of three activities explained through tables, activity descriptions, pictures, and icebergs. HLT that has been designed is used to anticipate student thinking that develops in each learning activity. The HLT that has been designed contains assumptions consisting of the learning stage, learning activities and basic concepts. Each activity in this study was designed using the form of mode of, mode for and formal knowledge oriented to the RME approach. As a form of evaluation, the researcher gave a worksheet to each student. The results of this study indicate that the activities implemented in the context of the kempreng game help students understand meaningfully and deeply the material for adding and subtracting integers.

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