The Power of Games to Learn Mathematics: An Overview

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Abstract

The central principle of Realistic Mathematics Education is that the learning of mathematics needs to be laid on meaningful situation; either meaningful problems or activities. Many researches found that activities of game playing are meaningful to students and can be effective tools for enhancing learning and understanding of complex subject matter. Consequently, this article focuses on the benefit of games to support the learning of mathematics and the role of teacher in conducting game-based learning.

Keywords: Realistic Mathematics Education, game-based learning, the role of teacher

A. Introduction

Many mathematics concepts are directly taught as an isolated concept at the formal level of young children (Castle & Needham, 2007; Kamii & Clark, 1997 and van de Walle & Folk, 2005). Teaching and learning of mathematics mostly focuses on the algorithm or procedure to solve problems at formal level of mathematics. However, in fact young children have difficulty in understanding the concepts of mathematics in the formal level (Van de Walle & Folk, 2005). Consequently, it is important not to start the teaching and learning process of mathematics from formal level. Freudenthal viewed mathematics as human activity, instead as subject matter that must be transferred from teachers to students (Freudenthal, 1991). This view underlies the development of Realistic Mathematics Education (RME).

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The central principle of RME is that mathematics should be meaningful to students. The meaningful mathematics can be achieved by giving contextual problem as the starting point of the teaching and learning. The term "realistic" in RME does not mean that the problems have to be encountered in daily life, but it means that the problems should be experientially real for student. In the process of teaching and learning, students should be allowed and encouraged to invent their own strategies and ideas. However, the different strategies and ideas of students have to be led to the formation of mathematics concepts as the final goal of the teaching and learning process.

The foundation of mathematics education in kindergarten and elementary school needs to be laid on doing meaningful activities or experiences, through which a connection is made between informal knowledge and the formal concepts of mathematics (Buys & de Moor, 2005 and Castle & Needham, 2007). Consequently, it is important to give young children experience-based activities that embody some basic concepts of mathematics. Experience-based activities are relevant with Freudenthal's idea that stresses mathematics as a human activity, instead of subject matter that has to be transmitted (Freudenthal, 1991). Freudenthal (*ibid*) proposed the need to connect mathematics to reality through problem situation because experience-based activities could contribute to the emerging of mathematical practices. For young children, game playing could be a problem situation, which is experientially real for them and, therefore, can be used as a starting point for their learning process. Game playing can form a natural part of the experience-based and development-focused activities for the teaching and learning of mathematics. In Indonesia, there are some (traditional) games that, without any consideration, embody mathematics concepts. Consequently, the central issue of this article is the use of games (especially Indonesian traditional games) as experience-based activities for teaching and learning of mathematics.

B. Realistic Mathematics Education

Realistic Mathematics Education was underlined by the idea of Hans Freudenthal that viewed mathematics as human activity, instead as subject matter that must be transferred from teachers to students (Freudenthal 1991). Based on Freudenthal's idea, the teaching and learning process of mathematics should be connected to contextual problems that experientially real for students. In spite of the use of contextual problem, the teaching and learning process should lead to the formation of mathematical concepts through the process of mathematization.

There are five tenets of realistic mathematics education defined by Treffers (1987), namely:

1. Phenomenological exploration

   Contextual problems are used as the base and starting point for the teaching and learning process. The teaching and learning process is not started from formal level but from a situation that is experientially real for student.

2. Using models and symbols for progressive mathematization

   The aim of this tenet is bridging from concrete level to more formal level using models and symbols.

3. Using students' own construction

   The freedom for students to use their own strategies could direct to the emergence of various solutions that can be used to develop the next learning process. The students' strategies in the activities are discussed in the following class discussion to support students' acquisition of the formal level of mathematics concepts.

4. Interactivity

   The learning process of students is not merely an individual process, but it is also a social process. The learning process of students can be shortened when students communicate their works and thoughts in the social interaction emerged in classroom.

5. Intertwinement

   The activities used in the teaching and learning process do not merely support learning for a single mathematics topic, but they also should support the learning process of other mathematics topics or concepts.

C. Game-based learning

Learning occurs when students process new information or knowledge in such a way that it makes sense to them. In a supporting environment, students can discover meaningful relationships between contextual problem situation and abstract ideas that will lead to the process of internalization of concepts through the process of (guided) reinventing, reinforcing, and connecting. However, student need attractive contextual situation as the starting point of their learning process. Games can be powerful and attractive contextual situation for students because one of the natural characteristics of a game playing is that it uses more action instead of word explanation. This characteristic will stimulate students' personal motivation and satisfaction in the learning process. Hence, games can encourage attractive and active learning in which students are more active in their learning process (Garris, Ahlers, & Driskell, 2002).

The other characteristic of game playing that can benefit and support the teaching and learning process is that many games are played in teams or groups. The teamwork created in a game playing can foster collaboration and interactivity among students (Kaptelin & Cole, 2002 and Sheffield, 2005). Furthermore, this characteristic can accommodate multiple learning styles and skills of students. Ricci, Salas & Cannon-Bowers (1996) and Sheffield (2005) found that game playing can reinforce mastery skills of students because game playing is effective tool for enhancing learning and understanding of complex subject matter. As an example is how Indonesian traditional games (i.e. benthik and gundu) can support second graders' learning of linear measurement (Ariyadi Wijaya, 2008).

Despite the aforementioned benefits of games in education, the use of games in the teaching can learning process cannot stand alone or independent. The games need to be followed by discussion in which the values and/or contents of the game are directed to the formation of mathematics concept. It is in line with the principles of experiential learning that was developed by Kolb. Kolb mentioned four stages of experiential learning, namely: (1) concrete experience, (2) reflective observation, (3) abstract conceptualization, and (4) active experimentation (Kolb, 1984). Game playing serves as a concrete experience in which students can develop strategies to solve problem-based game. The game playing is used as the base for the observations and reflections that transform experiences into abstract concepts. The strategies developed by students are directed to the formation of mathematics concepts in the process of reflective observation and abstract conceptualization. Active experimentation in the game-based learning can be the application of mathematics concept formed in the reflective and abstract conceptualization stage.

D. Games for mathematics learning

The following are examples of game that can be used in the learning of mathematics concepts:

1. Benthik

   Benthik is a game that is played by two teams (not an individual game). Each team will take a turn to hit a short stick using a long stick and then the distance of the short stick from the base is measured. The winner of the game is the team which greater accumulative distance.

   The process of measuring the distances of the short stick is about the concept of linear measurement, such as iterating unit and covering distance. It is natural that students will use their body parts (such as feet and hand) to measure the distance. The different measurement units used by students will result various numbers for the same measured distance. Teacher can introduce

the word “fair” for the game. The need to have a fair game can lead to the emergence of standard unit measurement. However, the standard unit measurement in this stage can be merely the same (not real standard) unit measurement. Therefore, the role of teacher starts to be very important to guide student to standard unit measurement; such as centimeter.

The distances in the game will not always be integer numbers; therefore Benthik can also be used for learning fraction.

2. Gundu

   The mathematics concepts embodied in the first part of Gundu game, namely when determining the order of the players. In this part all players have to throw their marble to a given hole or pole. The first player is a player whose marble is the nearest to the hole or pole.

   Students can use two strategies when determine the nearest marble, namely by comparison (when the different distances of the marbles is obvious to observe) and measurement (for the close distances). The development and formation of the concept of linear measurement in Gundu game is similar to that of Benthik game (look at figure 1).

3. Dakon atau congklak

   Dakon is a game that is played by two players and each player has a big hole as “a deposit hole” and some small holes (the number of small holes depends on the type of dakon). There are three versions of Dakon or Congklak, namely dakon with 10 holes, 12 holes and 16 holes. For the 10 holes dakon, there are 32 seeds or beads that should be put in the small holes at the beginning of the game (4 seeds or beads for each small hole). For the 12 holes dakon, there are 50 seeds or beads that should be put in the small holes at the beginning of the game (5 seeds or beads for each small hole). For the 16 holes dakon, there are 98 seeds or beads that should be put in the small holes at the beginning of the game (7 seeds or beads for each small hole).

The mathematics concepts embodied in Dakon game are counting and division. The counting emerges when students distribute the seeds or beads and count the final result in the "deposit hole". At the beginning of the game, each player has to distribute his/her seeds or beads in the small holes equally. The concept of division can be developed when the teacher change the rule of the game and giving various numbers of seeds or beads to students.

4. Ular tangga

   In Ular tangga game, the players have to throw a die and then move their pin in the numbers of steps as shown by the top of the die. When a player's pin stops at a stair, the player can directly "jump up" the pin to the top edge of the stair. On the other hand, a player has to "jump down" his/her pin to the head of snake when his/her pin stops at the tail of a snake. The winner of the game is the first player who arrives at number 100 as the final destination. Mathematics concepts that are embodied in Ular tangga are counting, addition and subtraction. The counting (i.e. counting one by one) emerges when a player/student moves his/her pin step by step. Addition concept emerges when a player does not move his/her pin step by step, but he/she adds the number shown by the die to the current position of the pin. Addition concept can be focused or emphasized by asking students about how many steps they get as an advantage when they get a stair. On the other hand, the disadvantage when students meet a snake can be used to emphasize the concept of subtraction.

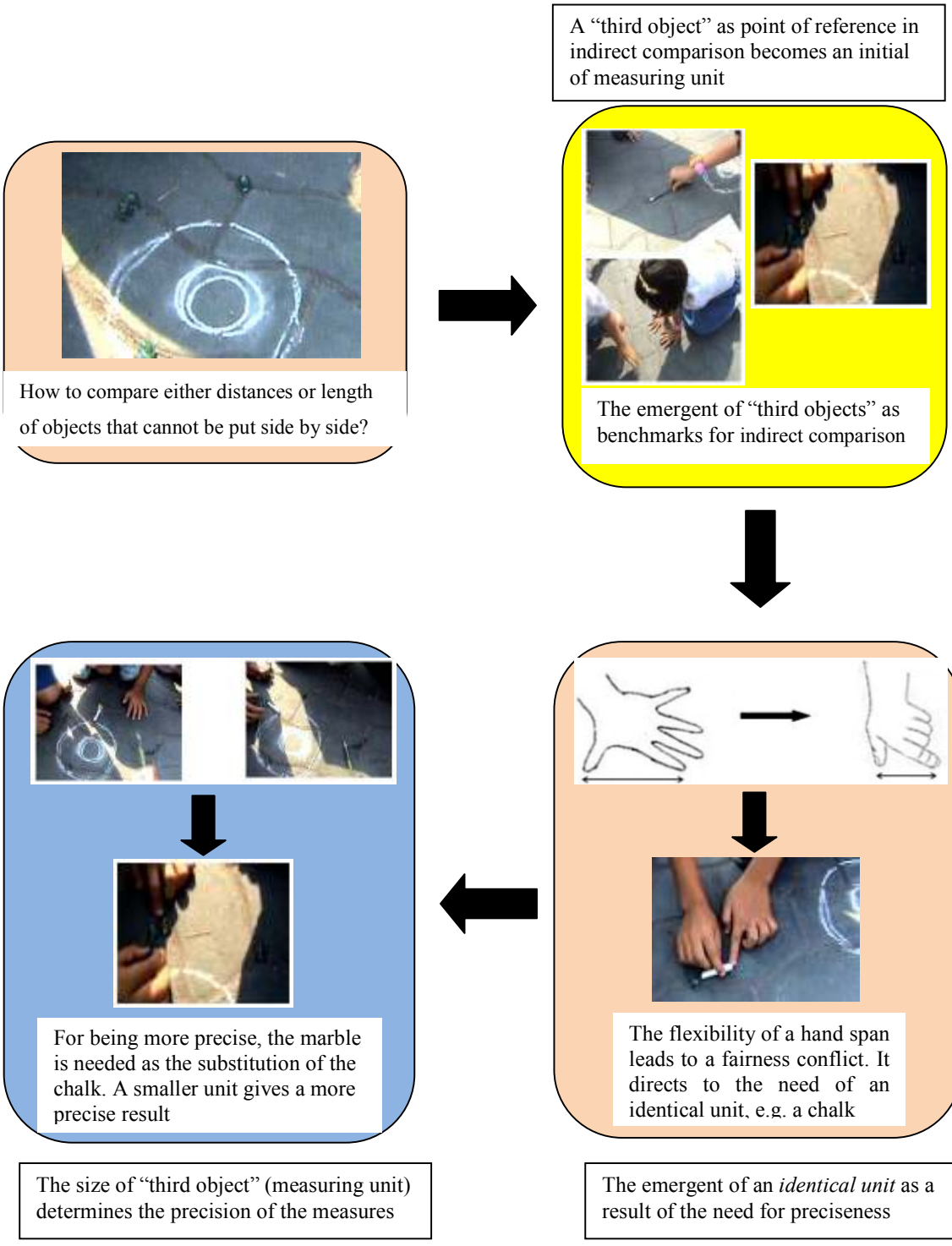

Figure 1. The scheme of students' process in eliciting basic concepts of linear measurement in Gundu game

E. The role of teacher in the game-based learning

Game playing provides a natural situation for social interaction, such as students' agreement in deciding a strategy for the fairness of their games (Ariyadi Wijaya, 2008). *Interactivity* as the fourth tenet of RME emphasizes on students' social interaction to support individual's learning process. The learning process of students is not merely an individual process, but it is also a social process that both perform simultaneously (Cooke & Buchholz, 2005; Lave & Wenger, 1991 in Lopez & Allal, 2007; Michelle & Cobb, 2003 and Zack & Graves, 2002). The learning process of students can be shortened when students communicate their works and thoughts in the social interaction both in game playing and class discussion.

As mentioned earlier, game playing needs to be supported by a class discussion to develop students' concrete experiences into mathematical concepts. Consequently, in the class discussion the teacher plays an important role in orchestrating social interaction to reach the objectives both for individual and social learning (Cooke & Buchholz, 2005 and Doorman & Gravemeijer, in press).

The roles of teacher in the class discussion can be elaborated in the following manners:

1. Providing students opportunities to present ideas

According to the third tenet of RME, it is important to start the class discussion by using *students' own construction*, such as students' strategies. The teacher, as the orchestrator of class discussion, should stimulate students to present their ideas as the starting point of class discussion (Cooke & Buchholz, 2005 and Sherin, 2002).

The following are examples of questions[2] that can be used by the teacher to stimulate students to express their ideas:

[2] Ariyadi Wijaya. (2008). *Indonesian Traditional Games as Means to Support Second Graders' Learning of Linear Measurement*

- *"When playing gundu, how did you determine the nearest marble?"*
- *"What did you use to measure the distances?"*

2. Stimulating social interaction

According to Vigotsky in Zack & Graves (2001), social interaction is the core of learning process because learners first construct knowledge in their interaction with people and activity or context. Therefore, a teacher should be a good orchestrator in provoking students' social interaction. The teacher could provoke social interaction by either making groups of students or asking questions. Generating micro discussions in a macro discussion in the class discussion can be the first step to stimulate the students to share and discuss their strategies.

The second strategy for stimulating social interaction is by posing appropriate questions (Cooke & Buchholz, 2005). The following are examples of questions to stimulate students' social interaction.

- *"Any other idea?"*

  This kind of question could serve both as a way of providing opportunity for self expression and also as a way for stimulating social interaction among students.
- *"Do you agree?"*

  It is natural in a class that not all participants are really involved in the discussion. Therefore, this kind of question can stimulate students to pay attention to the others' idea and argument.
- *"Can you show to your friend ... ?"* and *"Can you draw your strategies?"*

  These questions aimed to encourage students to communicate their idea.

3. Connecting activities

In supporting students' learning, it is important for the teacher to help children communicate and develop their ideas by elaborating upon what they already

know. An example[3] of this manner is when the teacher encourages students to perceive the concept of *measuring as covering space*. The teacher connects the *blank ruler activity* to *measuring using string of beads* activity by posing the following questions:

"Do you remember when we measure the distances using strings of beads? Where did we put our finger when we count "1"?"

By connecting the strings of beads to the blank ruler, the teacher tried to emphasize that a space on a blank ruler was a representation of a bead on a string of beads. Consequently, students should count the number of spaces, instead of the number of stripes, when they measure using a blank ruler.

4. Eliciting the mathematical concepts

The most important objective of a class discussion is transforming students' concrete experiences into mathematical concepts as mentioned by Cooke & Buchholz (2005) and Kolb in de Freites & Oliver (2006). Transforming a concrete experience into a mathematical concept can be facilitated by posing stimulating problem or conflict. For example[4] teacher can use fairness conflict to stimulate students to come up with an idea of a standard measuring unit.

"Is it fair for our game?"

When the students merely come up with the idea about a single person as a measurer, instead of using a tool [not person] as a standard unit, teacher posed the following question to give more guidance:

"If in a game there is no person who is willing to measure the distances using his/her own hand span [to be a referee or a judge]*, what should we do to obtain a fair result?"*

[3] Ariyadi Wijaya. (2008). *Indonesian Traditional Games as Means to Support Second Graders' Learning of Linear Measurement*

[4] Ariyadi Wijaya. (2008). *Indonesian Traditional Games as Means to Support Second Graders' Learning of Linear Measurement*

5. Asking for clarification

Asking for clarification is important for the learning process because it can investigate students' reasoning about their idea or strategies that could reveal both difficulty and achievement in students' learning process.

The following vignette[5] is an example of a critical part in a student's learning process that was revealed through asking clarification.

Dea : No. We should start from number "1"
Teacher : Why do we start from number "1"?
Dea : Because zero is nothing

The teacher's question is a kind of question for asking clarification and reasoning. From Dea's response, it seemed that Dea was still confused between measuring and counting object (cardinality). Therefore, from this invention the teacher could know which part of the learning process that should be developed.

Another advantage of asking clarification is when students' reasoning gives information about the strength of particular methods or strategies that could support students' learning process. The following vignette[6] shows how the word "*fair*" become really important in supporting students' learning process.

Teacher : So, can we use this strategy (i.e. using different steps) to measure the distances in our game?
*Students : No it is not because it is not **fair***
Teacher : What should we do?
*Haya : In a game, we will have a **fair** game if there is only one person who measures the distances …*

[5] Ariyadi Wijaya. (2008). *Indonesian Traditional Games as Means to Support Second Graders' Learning of Linear Measurement*
[6] Ariyadi Wijaya. (2008). *Indonesian Traditional Games as Means to Support Second Graders' Learning of Linear Measurement*

As a summary, by asking clarification we can know how a weakness of some students' progress could be diminished by providing a proper guidance. How the strength of particular methods or strategies offer an opportunity to develop students' learning process also can be found by asking clarification.

F. Conclusions

In general, the use of game playing in learning mathematics can give three benefits, namely: (1) motivational benefit, (2) social benefit and (3) conceptual benefit. Attractive is the characteristic of game playing that lead to the first benefit, motivational benefit. The attractivity of game playing can stimulate students' personal motivation and satisfaction in the learning process. Many games are played in groups or at least in pairs, therefore games can give social benefit. Teamwork or at least communication created in a game playing can foster collaboration and interactivity among students. The last benefit, conceptual benefit, means that game playing can be an effective tool for enhancing learning and understanding of mathematics concepts.

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