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MAP AS A TOOL TO SUPPORT THE DEVELOPMENT OF SPATIAL ABILITY

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Abstract

Spatial matters are involved in learning and teaching mathematics as a representation of the real world, including specific features of a graph and the surrounding text when solving a mathematical task. Maps are the main source of spatial information and spatial ability which is required to decode maps because of the spatial relation among visual elements. Therefore, a map can be a bridge between the real world and abstract world. In recent years, many studies that consider the spatial ability and map literacy were conducted. Realistic Mathematics Education in geometry makes extensive use of interesting spatial and map tasks, but unfortunately, research on the effects of this specific strand is lacking. Moreover, there is a lack of research of this domain in Indonesia. Realizing the importance of spatial ability and map literacy, we designed a learning sequence by using maps as a tool to support the development of spatial ability. The activity of learning sequence is based on the characteristic of PMRI (Pendidikan Matematika Realsitik Indonesia). The purpose of this study is to contribute the local instruction theory of spatial ability particularly map reading and map making (map understanding). To achieve the purpose of study, design research is chosen as an appropriate approach. The participants of the research were students of the second grade in elementary school. The learning experiment showed that students has prior knowledge in spatial ability so these activities that involve map as a material in learning instruction can support students to have experience and develop spatial ability particularly map understanding.

Keywords*: Spatial ability, map understanding , learning sequence*

INTRODUCTION

Spatial experience is strongly involved in the progression of cognitive children. Even, it starts before the development of spatial ability (Dickson, 1984). For instance, young children could point out the location of their toys or tell the route from house to the nearest shop. The sense of spatial can be interpreted as the ability to 'grasp the external world' (Freudenthal, in National Council of Teachers of Mathematics [NCTM], 1989, p.48). The capacity to understand and remember the spatial relations among objects is known as spatial ability. Spatial representations can be formed in pictures or diagrams that are useful for communicating ideas and information. Spatial ability is one of the great importances for success to solve many tasks in everyday life (Newcombe, 2010) including mathematical problem. For instance, using a map when you are travelling in an unfamiliar place or orienting yourself in your environment when you get the direction are such activities that require spatial ability.

Map is one of the spatial representations in daily life. According to Mackinlay (1999), maps are visual representation data that information is encoded through the spatial location of fixed position marks. Developing map understanding is important to increase the spatial ability particularly map reading because there is a positive relation between map understanding and spatial ability (Liben, 2008). It seems that maps can be used as a tool to support the development of spatial ability.

Based on Diezman & Lowrie's report (2007) informed that 10-13 year old children face difficult to understand the information on map. Therefore, it is necessary for students to have experience about map understanding in classroom activities. However, many educators do not give attention to map understanding and sometimes high jump to an abstract level in mapmaking and map reading (Sobel, 1998). Realizing the importance of spatial ability and map literacy, we will design learning activities that use maps a tool in the development of spatial ability. Thus, the purpose of this study is to contribute the local instruction theory of spatial ability particularly map reading (part of map understanding). Hence, the study is guided by the research question: *How is the role of map to support the development of spatial ability in learning activities?*

THEORETICAL FRAMEWORK

Spatial Ability

Some literatures use the terminology spatial ability, spatial skills, visual-spatial ability, spatial perception, visual cognition and ability of visualization interchangeably. These different terms have similar idea that related to the spatial knowledge yet it leads the different definition practically. The first definition came up by Lin and Peterson (1985), they used term 'spatial reasoning' refers to the skill representing, transforming, generating and recalling symbolic nonlinguistic information. A more comprehensive definition is given by Lohman (1993, p.20) that spatial ability is the ability to generate, retain, retrieve and transform well-structured visual images. According to Grattoni (2007), spatial ability is an ability that consists of declarative and perceptual forms of knowledge to transform, manipulate, combine and operate on this knowledge.

The three major components of spatial ability are space, tools of representation, and process of reasoning (National Research Council, 2006). These components are helpful for supporting children in grasping the world and developing mathematical thinking. In more detail, spatial ability has two factors of spatial ability: *spatial orientation* and *spatial visualization* (McGee, 1979). Based on McGee, *spatial orientation* involves the comprehension of the arrangement of elements within a visual stimulus pattern, the aptitude for remaining unconfused by chancing orientation in which a configuration may be presented and the ability to determine spatial relations in which the body orientation of the observer is an essential part of the problem; *spatial visualization* is an ability to mentally manipulate, rotate, twist or invert pictorially presented spatial visual stimuli. In a recent research, Contero et al. (2005) used three factors of spatial ability that are *spatial relations, spatial orientation, and spatial visualization.*

Map understanding

The fundamental knowledge of map understanding include five aspects (Wiegand, 2006): (1) understanding that map represent space, (2) understanding the alignment and perspective of the map, (3) understanding scale, (4) understanding symbols and texts, and (5) using maps to find the way. The model of map understanding is in line with spatial process. Map is such kind of representation in graphic form. It can be a bridge between the real world and abstract world for children to understand the other graphs in mathematics and science (Sobel, 1998). Liben (2008) stated that students in elementary have basic understanding about map. Therefore, developing this understanding is notable to increase the ability in reading maps properly.
However, teaching and learning in the classroom is limited and fail to connect map skills with other curriculum areas, including mathematics. Most students do not have enough understanding to use a map. According to Clement (2009), it is important to support children to: (a) build relationship among objects in space, (b) extend the size of the space, (c) link primary and secondary meaning and uses of spatial information, (c) build mental rotation abilities, (e) go beyond map skills to engage the actual use of maps in local environment, and (f) develop an understanding of the mathematics of maps. Children need to learn about model and maps including incidental and planned experience such as frequent discussion about spatial relation, finding a missing object, and finding the way back home. Teacher should provide instruction on using maps that explicitly relates to world space and maps. It might be started by generating four mathematical question (Clement, 2009): (1) Which way (direction), (2) How far (distance), (3) Where (location), (4) What objects (identification). Children must learn about mapping process and more sophisticated ideas of direction and location. In addition, they should develop navigation ideas, such as left, right, front, back, etc. Then, they might represent these ideas in simple route maps within the classroom.

The relation between mathematical thinking and spatial ability

Some studies show that spatial ability has positive correlation to mathematics achievement (Battista, 1990; Fennema and Sherman, 1977;Turgut, 2007). Grattoni (2007) found that students' practice spatial abilities would improve their math ability. Although, this study was in small participant, this finding is similar to another study (Hegarty & Kozhevnikov, 1999) that showed spatial representation could promote problem solving success. It seems that spatial skills play an important role in solving certain kinds of mathematical problem solving. For example, the problem from calculus and geometry often explore the relation between time and area.

Realizing this relation, the present study provides the learning sequence that considering maps as a tool to support the development of spatial ability. The activity is guided by five characteristic of RME (Treffers, 1987, cited in Zulkardi, 2002): (1) use of contextual problem, (2) use of models or bridging by vertical instruments, (3) use of students' contribution, (4) Interactivity, and (5) intertwining of learning strands.

Method

The approach of present study is design research because it considers design as a crucial part of the research. The main reason of use design research is to develop Hypothetical Learning Trajectory (HLT) together with instructional material and to contribute the local domain theory of Realistic Mathematic Education (RME)

especially in spatial aspects. The main result of design research is not a design that works, but the reason why, how, and to what extent it works. The research was conducted in three phases namely: (1) preparation phase, (2) preliminary teaching experiment (first cycle), and (3) teaching experiment (second cycle).

Data collection

Some data was collected during three phases: (1) preparation phase (literature review and classroom observation), (2) preliminary teaching experiment (video recording, students' written work and interview with students), (3) teaching experiment (video recording, students' written work and interview with students and teacher.

Participant

The research was conducted in Islamic elementary school state 2 Palembang (Madrasah Ibtidaiyah Negeri 2 Palembang). The subject of the research is students of second grade (7-8 years old). In the first cycle, it involved a small group of students consisting 5 students. Meanwhile, the second cycle was accomplished in a whole class consisting of 35 students.

Hypothetical Learning Trajectory

A HLT is a framework of learning activity that consists of learning goal, starting point, mathematical learning, and conjecture of students' thinking. In this chapter, we elaborated HLT that involve 5 activities in a learning sequence of map understanding related to the spatial thinking particularly spatial orientation. Spatial orientation is one of the main component of spatial ability that allows children to learn about orientating themselves, to take different perspective, to describe routes, to understand the shape/figure and realize the spatial relationship between objects (Van Nes& de Lange, 2007).These activity emphasize the three mathematical question that is related to the map problem (Clements, 2009) are (1) Which way? (direction), (2) Where? (location), and (3)What objects? (Identification).

Activity	Learning goal	Starting point	Mathematical learning	Conjecture of students' thinking
1. Read a school map	-Students understand their own school map -Students can read their school map -Students can realize the position of the room in school map	- Students recognize the shape square as a room on the map - Students realize the position of their class on the map	This activity offers the experience of map reading for students to do activity by using a school map in finding some hidden objects. Students should realize the position of the room on the map and follow the path. Also, this activity provide	• Students can read a map easily because they recognize the position of the object in the map to the real condition. • Students who can read a map easily will follow the path in the map to find the room. • Students understand the pictorial figures on the map.

			opportunity for students to understand the symbol or pictorial figure on the map.	• Students have difficulty to realize the position in the starting point. • Students get lost when they follow the school map to find the room.
2. Left versus Right	-Students understand about the term of orientation. -Students are able to distinguish between left and right. -Students can find the position of certain object by using orientation term.	-Students have already heard about the term of orientation. -Students have already known the position of objects	In this activity, students will know the position of their friend according the classroom map. Also, they will find the position of students sitting based on the instruction that using term of orientation. Therefore, this activity will encourage student to realize about the orientation.	• Some students will find the object correctly based on the instruction. • Some students have difficulty to distinguish left and right. • Students consider the use of their hand as the sign, such as right hand to write so another hand is left hand.
3. The map of palace	-Students get better understanding about direction -Students learn about simple navigation.	-Students are able to use and distinguish the left and tight side.	In the previous activity, students have already learned and about the term of orientation, such as left, right, etc. Those terms will be used in this navigational game that uses the map of palace. Students will write and fill the name of the room on the map of palace by following the direction from the teacher	• Students can follow the direction in navigational game. • Students write the name of the room in the wrong place because of wrong orientation. • Students consistent/inconsistent with the direction. • Students realize the point of direction.

RESULT AND DISCUSSION

From the teaching experiment, some finding of students' thinking can be drawn for each activity. In the first activity, students show that they have the ability to identify object in reading a school map. The following transcript showed it:

Researcher : Why do you take this way?
Fadil : Hmm,,because I know that there is a path between those room and we can walk there.

Fadil could realize a path in map so he decided to take the way. A path is the result of identifying the object in the map. A map can evoke the idea of identification of certain object. The idea of identification can be used in geometry field when identifying the object in 2 or 3 dimensional. For instance, students should realize the position of point or line in the plane. In order to know the position, the idea of identification should be integrated.

Researcher : How do you find the 'star' in this school map? Can you tell me the route?
Fadil : First, pass this way and turn and turn again, then just go straight forward.
Researcher : how many ways do you find to get the star?
Fadil hmm, two ways.

According to interview, some students could easily find and point out some different ways to reach a certain location. When reading a school map, students recognized the finishing and starting point, identified position of object around finishing and starting point, looked for some different ways and gave the direction. It seems that map has a role to generate students' thinking to consider the possibility of different way.
In the second activity 'left versus right', the main purpose is to distinguish left and right. Students should recognize the idea of point of view. After they know the point of view, they could decide the left or right side. In this activity, the position of students in the classroom map can be explored to establish the understanding left or right side.

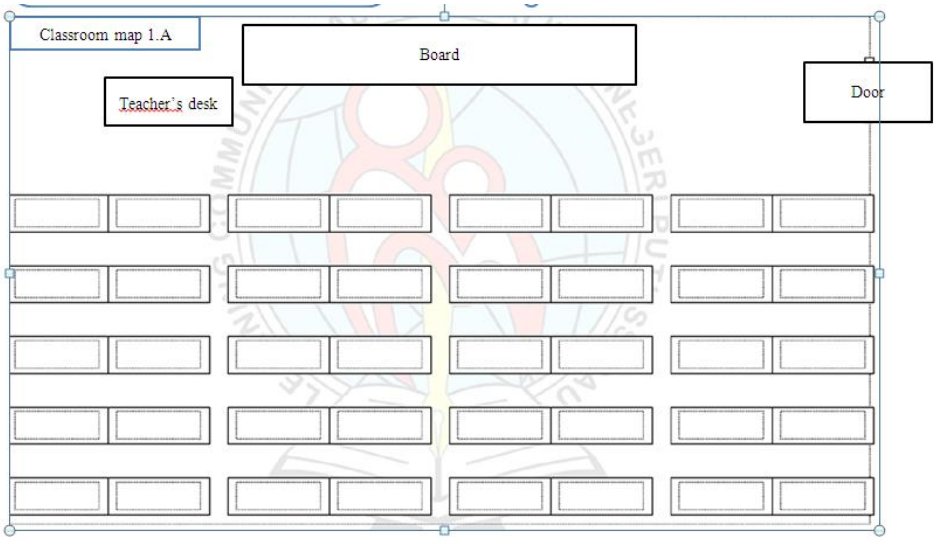

Figure 1. Classroom map

Then, the researcher asked student to answer the question related to the moving a certain objects in classroom map. In the beginning, students were encouraged to realize the position of the objects in that map. Subsequently, the questions are about the new position of the object based on the given direction. Some of students do not have difficulty to answer this question. This finding shows that the students has already known about the position and its moving which is related to the fundamental knowledge in spatial orientation.

In the previous activity, students have already learned to distinguish left and right side. So the last activity is that student played a simple navigational game. In this activity, students worked in a group consisting of 2 students. They were asked to fill the name of room in the map palace based on the instruction. Almost students could answer it correctly. It seems that the students did not face the difficulty to play this navigational game since the students have already deal with the direction in the prior activity. It shows that there is continuity among activities.

At the end of activity, the researcher asked two students to tell again and explain about the room in the map of palace by using their own sentence.

Researcher	*: can anyone tell again about the position of the room in the map palace?*
Fadil	*: Yes, I can.*
Researcher	*: The king enter the palace then …*
Fadil	*: The king enter the palace, go straight forward, it is a living room, turn the left is lounge, and left again is king's room. In front of king's room, there is a dining room, then turn, it is study room.*
Farhan	*: Turn the left or turn the right?*
Fadil	*: Turn the right, it is study room. Turn the right of study room, there is a kitchen. The right side of living room is music room and princess' room.*

The transcript above shows that Fadil is able to describe the position of the room by using the direction term, for instance turn the left and right. The navigational game is fruitful to enhance the basic ability in spatial orientation since students will be able to orient spatially with respect to a given object or scene. Therefore, students still require more opportunity to improve and support the development of spatial ability based on the level age.

CONCLUSION

Spatial ability is capability to understand the mental manipulation of objects in 2D and 3D space. Maps as the main tool in learning process are chosen for two important roles: First, a tool for mental imagery. Mental imagery is mental that related to the images in your mind to interpret correctly the image corresponding with the prior knowledge. Second, a tool is to evoke the idea of identification, location and direction in mathematical understanding. The present study suggests that the appropriate learning in classroom activities can improve spatial ability. For further study, it is

possible to use the other maps in order to support the development of spatial ability particularly mathematical understanding.

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