

SPATIAL THINKING ABILITY IN ELEMENTARY SCHOOL

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Abstract

Spatial thinking ability is the ability to mentally manipulate and rotate an object in solving two-dimensional and third-dimensional geometric problems as well as the ability to imagine the shape of an object from a different perspective in solving three-dimensional geometric problems. This spatial ability is very necessary for students because good spatial abilities will also support good understanding of mathematics. Apart from that, students also need spatial abilities to solve everyday problems, such as looking at a map, explaining their position and so on. This spatial ability consists of spatial visualization, spatial rotation and spatial orientation. To improve spatial abilities, teachers must be creative in designing learning by using various media or teaching aids that are appropriate to the material being studied.

Keywords: Spatial thinking skills, Geometry, Elementary education

Abstrak

Kemampuan berpikir spasial merupakan kemampuan memanipulasi dan merotasi secara mental suatu objek dalam menyelesaikan masalah geometri dimensi dua dan dimensi tiga serta kemampuan membayangkan bentuk suatu objek dari perspektif berbeda dalam menyelesaikan masalah geometri dimensi tiga. Kemampuan spasial ini sangat diperlukan bagi siswa karena dengan kemampuan spasial yang baik akan mendukung pemahaman matematika yang baik pula. Selain itu juga kemampuan spasial diperlukan oleh siswa dalam menyelesaikan masalah sehari-hari, seperti melihat peta, menjelaskan posisi keberadaannya dan lain sebagainya. Kemampuan spasial ini terdiri dari visualisasi spasial, rotasi spasial dan orientasi spasial. Untuk meningkatkan kemampuan spasial ini guru harus kreatif dalam merancang pembelajaran dengan menggunakan berbagai media atau alat peraga yang sesuai dengan materi yang dipelajari.

Kata Kunci: kemampuan berpikir spasial, geometri, pendidikan dasar

INTRODUCTION

Various studies have been conducted on spatial thinking abilities, but there is still little research that specifically discusses spatial thinking abilities in elementary school students. Elementary school is a place to lay the foundation for correct and meaningful understanding in learning, especially in learning mathematics. One of the mathematics materials studied in elementary school is geometry. Geometry is a branch of mathematics that is concerned with the shape, size, composition and proportion of objects along with their properties and their relationship to each other (Yanty & Nasution, 2017). Yanty and Nasution (2017) also stated that geometry is one of the materials that students still consider difficult.

When children start to know mathematics in kindergarten, then in elementary school children begin to understand mathematics which is studied step by step. One of the materials studied is geometry. When children are in kindergarten, they are introduced to geometric shapes. Furthermore, when they enter elementary school, they must have more abilities than those taught in kindergarten, namely being able to say the names of these geometric shapes. However, there are still many students who in certain classes should already understand the material at that class level but are still not as expected. This causes students to have difficulty solving problems related to the material. Some parts of math problem solving relate to spatial abilities. Good spatial conceptualization is an asset for students in understanding other mathematical concepts (Tambunan, 2006; Harmony & Theis, 2012; Febriana, 2015). Using spatial examples such as making charts and graphs can help children master mathematical concepts. Likewise, understanding the concept of division and proportion depends on the spatial experience that precedes it (Clements in Tambunan, 2006). Apart from that, spatial processes support the development of mathematical skills, especially in facing new tasks for students (Lowrie & Kay, 2001; Harris & Lowrie, 2018). Research also states that there is a significant influence between spatial abilities on students' mathematics learning outcomes (Harmony & Theis, 2012).

The national curriculum in Indonesia, from elementary school to university level, requires students to be able to master geometry material which requires spatial abilities (Syahputra, 2013). Thus, spatial ability is a curriculum demand that must be accommodated in classroom learning. In summary, based on the Royal Society/JMC Report, the aim of teaching geometry is to develop spatial awareness, geometric intuition and the ability to visualize (Jones, 2002). Therefore, spatial thinking is essential for learning and cognition. Additionally, since its inception, NCTM (1989) has advocated that spatial reasoning has an important role in mathematics education throughout pre-K12. Furthermore, NCTM (2006) has recommended that spatial reasoning be emphasized in kindergarten with more time allocated than numeracy. NCTM (1989, 2000, 2006) has also recommended that children's early school experiences with mathematics should include spatial reasoning approaches as part of the subject's introduction (Hawes, Moss, Caswell, Naqvi, & MacKinnon, 2017).

However, the reality that occurs in Indonesia is that formal education does not provide enough stimulus for the development of children's intelligence, because it only develops certain abilities, which are more focused on the function and role of the left side of the brain, and less stimulating the function and role of the right side of the brain (Harmony & Theis, 2012). However, now there is little effort to develop children's various abilities, especially in schools that assess children of various intelligences. One of the intelligences that is

considered is spatial intelligence, which according to Gardner, spatial abilities can develop the function and role of the right hemisphere of the brain (Atmajaya, 2008). The Committee on Support for Spatial Thinking (2006) views spatial thinking as a basic and essential skill that can be learned, can be taught formally to all students, and can also be supported by technology, appropriately designed tools/media, and curriculum. With the right learning and the appropriate level of technological support, making spatial thinking skills becomes an invaluable, lifelong habit.

The importance of geometric abilities and spatial thinking for students in studying further material and to achieve an understanding of mathematics, therefore a teacher must help students improve/develop geometric abilities and spatial thinking to understand geometry and spatial relationships well by providing learning programs and appropriate facilities (Korkmaz, 2017). Spatial thinking ability is not an ability that cannot be trained, but this skill can be improved by doing exercises for students (Seah & Horne, 2018). This shows that teachers need creativity in carrying out appropriate learning to improve spatial thinking skills. One way that teachers can do in learning is to develop teaching materials that are related to visuals, for example using media, props, puzzles or games that support learning so that students feel happy and not burdened with the material, as a result students can get a good learning experience. fun and meaningful that supports problem solving in everyday life.

LITERATURE REVIEW

1. Definition of Spatial Thinking

Spatial Intelligence is one of 8 multiple intelligences according to Gardner (1983). The ability to perceive the spatial world accurately. This intelligence includes the ability to imagine, present ideas visually-spatially, and orient oneself appropriately in the spatial matrix. When explaining the center of spatial intelligence, Howard Gardner (1983) wrote that the center of spatial intelligence is the ability to perceive the visual world accurately, transform and modify one's visual experience, even when there are no relevant physical stimuli. Students who have this intelligence will tend to create imaginative shapes in their minds or the ability to create three-dimensional shapes as found in adults who are statue sculptors or architects (Hamzah, 2007).

Spatial ability is one of the abilities required in learning mathematics, especially in geometry. However, to define what spatial ability is, there are various definitions from several experts regarding spatial thinking, including Lohman (1993 & 1996) defining spatial thinking as the ability to produce, maintain, retrieve and change well-structured visual images. Likewise, Hawes and friends adhere to a definition of spatial thinking which is mostly related to the formation and manipulation of visual spatial mental images (Hawes et al., 2017). "Spatial reasoning includes answering questions about generating images, examining images, changing and operating on images, and maintaining images in other mental operations" (Owens, 2013).

Gardner stated that spatial ability is the ability to capture the world of space accurately or in other words the ability to visualize images, which includes the ability to recognize shapes and objects precisely, make changes to an object in one's mind and recognize these changes, describe a thing or object. in the mind and change it in real form,

expressing data in a graph as well as sensitivity to balance, relationships, color, lines, shapes and space (Al Arif, 2004).

Spatial ability concerns the ability to represent, transform and recall symbolic information (Linn & Petersen in Yilmaz, 2009). Spatial ability is the ability to mentally manipulate and rotate an object in solving three-dimensional geometric problems as well as the ability to imagine the shape of an object from a different perspective in solving three-dimensional geometric problems where: 1) Manipulation is how students mentally change an object into a different shape and recognize changes in the position of elements within it. 2) Rotating is how students mentally change the position of an object and recognize changes in the position of the elements in it. 3) Imagining is how students represent in writing and orally the shape of an object from different perspectives. (Febriana, 2015).

Based on the information above, it can be said that spatial ability is the ability to use flat shapes and spatial shapes. Flat shapes and spatial shapes are closely related to mathematics. Plane shapes and space shapes are found in geometry material. Thus, mathematics is related to spatial intelligence (Wardhani, Irawan, & Sa'dijah, 2016). So, it can be concluded that spatial ability is an abstract concept which includes spatial perception involving spatial relationships including orientation to complex abilities involving manipulation and mental rotation. Spatial abilities require understanding left-right, understanding perspective, geometric shapes, connecting spatial concepts with numbers and the ability to mentally transform visual images.

2. Types and Indicators of Spatial Thinking

According to initial psychometric studies, spatial abilities are divided into 2 factors, namely spatial visualization and spatial orientation (Seah & Horne, 2018). Furthermore (Ramful, Lowrie & Logan, 2017) divides spatial abilities into 3 parts, namely mental rotation, spatial orientation and spatial visualization. McGee (in Hegarty and Waller, 2005) explains the two components that make up spatial abilities, namely spatial visualization and spatial orientation. Spatial visualization concerns the ability to manipulate, rotate, or flip an object without referring to itself. Meanwhile, spatial orientation is characterized as an understanding of the arrangement of elements in a visual stimulus image and the ability to remain unconfused by changes in orientation in a spatial configuration. Spatial orientation is often defined as the ability to imagine the shape of objects from different observer orientations (perspectives) (Hegarty and Waller, 2005).

Kimura (1999) defines that there are six spatial factors consisting of: spatial orientation, spatial location memory, targeting, spatial visualization, disembedding, and spatial perception. Meanwhile, Linn and Petersen (National Academy of Science, 2006) group spatial abilities into three categories, namely: (1) spatial perception, (2) mental rotation, and (3) spatial visualization. To measure spatial abilities according to Nano, observational abilities, logical consistency, the ability to classify images and conceptual thinking are required. The indicators of spatial ability consist of: perceptual thinking, image classification, logical consistency, image identification ability (Harmony & Theis, 2012). Perceptual thinking ability is the ability to carry out perception which includes sensory sensitivity, attention, orientation in space and time and speed of perception. Image classification ability is the ability to find differences and similarities between symbols in

images (Bangkit, 2009). Logical consistency ability is the ability to find relationships in numbers and find relationships in the symbols used (Bangkit, 2009). The ability to identify images is the ability to imagine the space of the structures forming the given images.

According to Sutton, the spatial ability construct is divided into 5 parts, namely spatial perception, spatial reasoning, spatial sections, mental rotation, and spatial orientation (Sutton, 2011). Measuring spatial abilities can be done using various tests, including Sutton et al. Using the 3DAT spatial ability test, which is a computer-based instrument that measures choice accuracy and response time. The 3DAT used consists of five subjects. Each subtest aims to measure separate factors of spatial ability, often referred to as spatial elements or skills. 3DAT is delivered online and can be used for research purposes or as a spatial diagnostic test. The test consists of 30 items divided into five subtests. The test material consists of straight lines and flat areas, but the shape is different and with a new design. Below is a description of the definition of subtests:

- a. Mental cutting: presenting a 3D view of an object crossed by a cutting plane. The idea is to identify the resulting 2D shape of the surface when the top of the object is removed. Participants choose from four options. This subtest identifies spatial skills which are defined as spatial sections.
- b. Building representations: 3D views of objects based on the arrangement of cubes displayed with clearly labeled front and right views. Participants were asked to identify the correct 2D rear view of the object from four given options. This subtest identifies spatial skills which are defined as spatial perception.
- c. Transformation: A top view of the object in 2D format is presented and the viewing direction is provided as a reference point. An object is an arrangement of cubes with numbers in strategic positions to indicate the shape of a 3D object. Participants decide which of the four 3D options matches the given viewing directions. This subtest identifies spatial skills which are defined as spatial reasoning.
- d. Mental rotation: Participants decide whether the rotated isometric projection of an object matches the isometric projection of a standard or its mirror image. The object on the left is always in the same position and is a reference. The object on the right can be the same or a mirror image of the reference and its orientation in the XY plane can be different. This subtest identifies spatial skills defined as Mental rotation.
- e. Dot coordinates: Participants are shown an isometric projection of a 3D Cartesian coordinate system and a text description of the position of a point in that system (Bore and Munro, 2002). From four orthogonal projections, participants chose the projection that matched the description. This subtest identifies spatial skills which are defined as spatial orientation (Sutton, Williams, & Tremain, 2016).

Pittalis and Christou adopted Lohman's model which classifies spatial abilities into 3 factors (Pittalis & Christou, 2010), namely spatial visualization (Vz), spatial orientation (SO) and spatial relations (SR). Vz is defined by difficult spatial tasks that require a more complex sequence of transformations of spatial representations and stimuli. For example, a spatial visualization test requires the examinee to imagine the creases and creases of a sheet of paper that, when folded, has been perforated one or more times. Spatial orientation is defined as the student's ability to remain unconfused by changes in the orientation in which a spatial configuration may be presented. Awareness of whether one object is to the right or left,

higher or lower or closer than another is the basic property of this factor. Spatial relations are defined as the ability to mentally rotate spatial objects quickly and correctly (Colom et al., 2001). The spatial relations test requires rapid performance of 3D and 3D mental rotation items. The following is an example of the test used:

Table 1 Examples from the spatial abilities test

Factor	Test	Example
VZ	<p>Surface-development</p> <p>The diagram shows how a piece of paper might be cut and folded to make the solid form. Dotted lines show where the paper is folded. Indicate which lettered edges in the drawing correspond to numbered edges or dotted lines in the diagram (Segment "3" corresponds to the edge "LM").</p>	
SO	<p>Image Perspective</p> <p>Indicate the front view of the solid according to the observer's angle view.</p>	
SR	<p>Object-Rotation</p> <p>There are four solids under the line. Which one of them is NOT identical to the solid above the line?</p>	

Source: Pittalis & Christou, 2010

Wahdin (2015) stated that indicators of spatial ability consist of:

- a) State the position between the elements of a spatial structure;
- b) Identify and classify geometric images;
- c) Imagine the shape or position of a geometric object viewed from a certain point of view;
- d) Construct and present geometric models drawn on a flat plane in a spatial context; And
- e) Investigate a geometric object.

According to Roland Guay (in Subroto, 2016) from Purdue University, spatial abilities are divided into 3 dimensions, namely the development dimension, view dimension, and rotation dimension. According to Maier, spatial abilities are divided into five dimensions of spatial abilities, namely: Perception, Visualization, Rotation, Relationship, Orientation Ability Dimensions (Maier, 1996). Maier stated that each indicator of spatial ability has its own characteristics for measuring students' spatial abilities, namely as follows:

1) Spatial Perception

Spatial perception is the ability to observe a spatial structure or parts of a spatial structure that are placed in a horizontal or vertical position. The mental process of this element is static, meaning that the relationship between the subject (observer) and the object (object being observed) changes, while the spatial relationship between parts of the object

does not change. This element can be trained using the water level test and rod and frame test (Prabowo and Ristiani, 2011).

2) Spatial Visualization

Spatial visualization is the ability to imagine or provide a description of a spatial form whose parts experience change or movement. The mental process of this element is dynamic, meaning that the spatial relationship between objects changes. For example, building space is identical to the image of the object. (Prabowo and Ristiani, 2011)

3) Mind Rotation (Mental Rotation)

Mind rotation includes the ability to rotate a second or third dimensional structure quickly and precisely. This capability is increasingly important now as more people work with graphics software. The mental processes of this element are dynamic. (Prabowo and Ristiani, 2011)

4) Spatial Relations

Spatial relations is the ability to understand the shape of an object or the parts of that object and understand the relationship between one part and another. For example, someone must be able to recognize the identity of an object shown in a different position. The mental processes of this element are static. (Prabowo and Ristiani, 2011)

5) Spatial Orientation

Spatial orientation is the ability to find one's own guidance physically or mentally in space, or to orient oneself in a particular spatial situation. The mental processes of this element are dynamic. For example, a shape is seen from various directions. (Prabowo and Ristiani, 2011)

3. Measuring Tool for Spatial Thinking Ability

Measuring spatial ability can be done using existing measuring instruments of various types according to the purpose to be measured. Among the measuring instruments used are:

- a. 3DAT is a computer-based instrument that measures choice accuracy and response time. The 3DAT used consists of five subjects. Each subtest aims to measure separate factors of spatial ability, often referred to as spatial elements or skills (Sutton, 2011).
- b. The Purdue Spatial Visualization Test (PSVT). This test tool consists of 3 subtests, namely Visualization of Developments (PSVT-D), Visualization of Rotation (PSVT-R) and Visualization of Views (PSVT-V). This instrument is a common instrument and is widely used to measure spatial abilities. The research that uses this test includes Karakus and Aydin with the research title "The effects of computer algebra system on undergraduate students' spatial visualization skills in a calculus course" (Karakus & Aydin, 2017), and also research conducted by Kosa entitled Effects of using dynamic mathematics software on preservice mathematics teachers' spatial visualization skills: the case of spatial analytic geometry (Kösa, 2016).
- c. Spatial ability test in solving geometric problems ((TKSMG), this test is in the form of geometric questions which are arranged based on indicators of spatial ability, namely frame of reference, conservation of distance, spatial representation, mental rotation, and projective relationships (Asis, Arsyad, & Alimuddin, 2015).
- d. Geometry and spatial thinking skills test called the Geometric and Spatial Thinking Skills Test (GEOST-ST). This test evaluates the geometric and spatial thinking skills of children

aged 48 to 66 months. It was developed by Korkmaz (2017). GEOST-ST consists of two sub tests consisting of geometric thinking and spatial thinking. Shape skills, Area and Symmetry for geometric thinking and Spatial Orientation and Spatial Visualization skills for spatial thinking. This test consists of 12 items for geometric thinking and 13 for spatial thinking, totaling 25 items. This test is implemented one by one for each child, based on games and tasks (Korkmaz, 2017).

METHODS

The methodology used in writing this article is a literature review of elementary school students' spatial thinking abilities in mathematics learning. This study was obtained from several sources relevant to the topic discussed in this article. Because in accordance with Nazir's (1988) statement, literature review is a data collection technique by reviewing various books, literature, notes and various reports related to the problem that must be solved. Sarwono (2006) also expressed the same thing that literature study is studying various reference books and previous research results that are relevant to obtain a theoretical basis for the problem to be researched.

RESULTS AND DISCUSSION

Spatial ability is one of the abilities that can be trained by providing appropriate treatment. This is supported by several studies that apply various models or use various media to improve students' spatial abilities. Among them is research conducted by (Weckbacher & Okamoto, 2015) which implemented QuickDraw in classroom learning. From the results of this research, students expressed their learning experiences by using Quick Draw to produce and interpret visual images to facilitate learning mathematical concepts in a more meaningful way. This activity can also attract students' attention to focus on the task at hand, and can also encourage them to openly engage with each other in a way that does not blame each other. Therefore, the use of Quick Draw will be necessary to determine students' actual improvement in spatial abilities. Another research was conducted by Toptaş, Çelik, & Tugce Karaca by exploring the effect of a 3D Modeling program on the spatial abilities of grade 8 students through an experimental research design. The results found in the study were that the posttest success rate increased after implementation in terms of differential aptitude, mental rotation and spatial visualization. On the other hand, despite the relevant literature, female students were observed as better performers compared to males on post-implementation of the measurement instrument (Toptaş, Çelik, & Tugce Karaca, 2012).

Aytaç Kurtul and Canda Uygan also conducted research using Google SketchUp, which is 3D dynamic sketching software which is usually used to design 3D building models, which can be applied to geometry learning. From the research results, it was found that there were significant differences between the group that used Google SketchUp and the group that did not use Google SketchUp. SketchUp-based activities and projects influence students' spatial visualization abilities (Kurtuluş & Uygan, 2010). Another study was conducted using a program based on origami paper and pop-up techniques, called Think3d!. Think3d! uses embodied tasks, such as folding and cutting paper, to practice two- to three-dimensional spatial thinking. This study is the first to examine the effects of embodied spatial training on

elementary school students' mathematics performance in the classroom (Burte, Gardony, Hutton, & Taylor, 2017).

Apart from several media and software mentioned in several studies above, there is also other software, namely Archimedes Geo3D, GeoGebra, or POV-Ray. The basic spatial geometry program for children that can be used is BAUWAS, where blocks can be placed in a $10 \times 10 \times 10$ grid (Foerster, 2017). And there is also a multimedia learning software program called GeoCAL. This program is based on van Hiele's theory of levels of geometric thinking, which consists of four levels: recognition, visual association, description / analysis, and abstraction / relations. (Chang, Sung, & Lin, 2007).

Learning will be successful if the teacher treats students according to their needs, namely understanding students' weaknesses and applying models or using media that is appropriate to the learning topic. Based on a survey and analysis of 709 students conducted by Seah & Horne, it was found that classroom experience can improve students' spatial and reasoning skills (Seah & Horne, 2018). Thus, teachers need to provide meaningful learning experiences and involve students directly.

CONCLUSION

Based on the explanation above, it can be concluded that the ability to think spatially is an urgent ability for students, especially elementary school students, which is the place to instill the foundation of early mathematical concepts. With good spatial thinking skills, students will find it easier to solve problems in everyday life. Apart from that, this ability is also an ability that is very necessary for studying other fields of knowledge such as geography, engineering and science. To find out and measure students' spatial thinking abilities, this can be done by looking at the spatial factors that students master, such as spatial visualization, spatial orientation and spatial rotation.

Because spatial abilities can be trained or taught, teacher creativity is needed in designing and preparing lessons that are appropriate to the material being taught. One way that teachers can do in learning is to develop teaching materials related to visuals, for example using media, props, puzzles or games that support learning so that students feel happy and not burdened with the material provided by the teacher, as a result students can gain a fun and meaningful learning experience that supports problem solving in everyday life.

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