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Students' Spatial Performance: Cognitive Style and Sex Differences

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Abstract. This study aims at describing the students' spatial abilities based on cognitive styles and sex differences. Spatial abilities in this study include 5 components, namely spatial perception, spatial visualization, mental rotation, spatial relations, and spatial orientation. This research is descriptive research with qualitative approach. The subjects in this research were 40 students of junior high school, there were 1 male FI, 1 male FD, 1 female FI, and 1 female FD. The results showed that there are differences in spatial abilities of the four subjects that are on the components of spatial visualization, mental rotation, and spatial relations. The differences in spatial abilities were found in methods / strategies used by each subject to solve each component problem. The differences in cognitive styles and sex suggested different choice of strategies used to solve problems. The male students imagined the figures but female students needed the media to solve the problem. Besides sex, the cognitive style differences also have an effect on solving a problem. In addition, FI students were not affected by distracting information but FD students could be affected by distracting information. This research was expected to contribute knowledge and insight to the readers, especially for math teachers in terms of the spatial ability of the students so that they can optimize their students' spatial ability.

1. Introduction

Spatial ability is a capability to visualize the image. According to Gardner [1], spatial ability is a skill to capture the world of space appropriately or, in other words, it is a skill to visualize the image. Everyone's spatial ability was definitely different because of his or her different characteristics. In accordance with Eddy [2], there are five factors that distinguish the characteristics of an individual: age, motivation/attitude, personality, learning/cognitive style and aptitude/intelligence. In this study, the characteristics of this research subjects used are the cognitive style. Cognitive style is a typical way of learning, both in terms of how to receive and manage information, attitudes toward information, and habits related to the learning environment. It is in accordance with the opinion of Zhang and Sternberg [3] who state that the cognitive style is an individual characteristic in thinking, feeling, remembering, solving problems, and making decision. Witkin and Goodenough [4] categorize cognitive styles in several types, one of which is the field-independent (FI) and field-dependent (FD) cognitive style. According to Witkin and Goodenough, the individuals who have a field-independent cognitive style are able to separate elements from the background so that it is easy for them to rebuild new information. Meanwhile, the individuals who have a field dependent cognitive style tend to be difficult to separate an item from an intact part that makes it difficult to rebuild new information. Each individual can be divided into two sexes, namely male and female. In addition to cognitive style factors, from the differences in sex, there are differences in problem-solving skills between women and men. Zhu [5] states that the gender differences in using strategy during mathematical problems solving fall into two classes: (a) on one hand, gender difference within groups



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with high-level spatial skills arise through the ability of integrating many problem-solving strategies, in which females do better than males; (b) on the other hand, gender difference within groups with low-level spatial skill arise from the ability in using other skills to compensate, in which males outperformed females. Naurzalina et al.'s study [6] also found that males tend to spend less time and made less mistakes compared to females. In this study, the researcher took the junior high school students because according to psychological theory Piaget [7], they should have been at the stage of formal operations so that students were expected to be able to think abstractly. Nevertheless, there are still many students who will have difficulty in thinking abstractly about the geometry that is widely used in math. Thus, the spatial ability of junior high school students is low.

In fact, the spatial ability of the students is still underperformed. The fact was revealed through a study conducted by Guven & Kosa [8], which states that the students' spatial skills are quite low. In particular, the average of 12 questions in Views section is 3.8 and in general the average of 36 questions is 15.7. The finding shows the insufficiency of students' spatial skills. It is surprising that although the students have learnt three-dimensional objects and their features in the early stages of elementary school as well as studied the three-dimensional objects in various lessons in Turkey, the averages value are still low.

Based on the research background, the purpose of this study is to describe the spatial ability of male and female of junior high school students who have cognitive field independent and field dependent. Spatial abilities in this study include five components, namely spatial perception, spatial visualization, mental rotation, spatial relations, and spatial orientation. This research is a descriptive research with qualitative approach which began by determining the subject using GEFT and math ability test, and then it continued by giving spatial ability test and interview. The validity of the data was checked through the use of triangulation. Data reduction, display data, and conclusion are parts of data analysis used in this study. The results show that there are differences in spatial abilities of the four subjects that are on the components of spatial visualization, mental rotation, and spatial relations. The differences in spatial abilities are found in the methods / strategies used by each subject to solve each component problem. The differences in cognitive styles and sex difference suggest different choice of strategies used to solve problems. This research is expected to contribute knowledge and insight to readers, especially for math teachers about the students' spatial ability so that can optimize it in their own classroom context.

2. Spatial Ability

According to Maier [9], spatial ability is divided into 5 components. *Spatial perception* is the ability to view the objects from vertical or horizontal viewpoint. *Spatial visualization* comprises ability to visualize a configuration in which there is movement or displacement among (internal) parts of the configuration.

Mental rotation involves the ability to rapidly and to accurately rotates 2D- or 3D- figures. *Spatial relation* refers to the ability to comprehend the spatial configuration of objects or parts of an object and their relation to each other. *Spatial orientation* is the ability to orient oneself physically or mentally in space.

3. Method

This research is a qualitative descriptive research. This study was conducted to describe the spatial characteristics of junior high school students in terms of cognitive style and sex differences in detail and systematic way. In determining the research subject in this research, the researcher involved 30 male and 30 female junior high school students.

The subject selection process of each category was done in the following way. Students were given mathematics test to measure their mathematical ability. It was done to choose the subjects who have equal mathematical ability, i.e. maximal score difference is 27. After the researcher gave mathematic ability test, students were given cognitive style test i.e. Group Embedded Figure Test (GEFT) developed by Witkin et al [10] and defined subject groups FI and FD according to the scores obtained

by the subjects. The students who got score between 0-9 were categorized as groups of students who had FD cognitive style and between of 10-18 were categorized as groups of students who had FI cognitive styles.

Then, it is chosen that the subject **24** are one male with FI cognitive style, one female with FI cognitive style **24**, one male with FD cognitive style, and one female with FD cognitive style. The selection was based on the test results and the teacher's consideration of the students' ability in mathematics and communication. **42**

There were four subjects selected and given spatial ability tests. The spatial ability test that was given to the subjects consists of 6 questions and should be done within 60 minutes. The spatial ability test was adopted from Maier. After a spatial ability test was performed, the four subjects were interviewed to complete the data that could not be revealed through a written test. Then, the researcher checked the result of the test and interviewed the subjects in different **11** time to check the validity of data. In this study, the researcher made use of time triangulation. The analysis of data was carried out by firstly reducing data, displaying data, and drawing conclusion (Miles & Huberman [11]). The conclusion was sought to understand the characteristics of described students' spatial abilities based on spatial ability tests and interview results.

4. Spatial Ability Test

Spatial ability test was used to know student's spatial performance. In this test, the students are given 60 minutes to answer 6 questions related to spatial abilities. The spatial ability test appears in Figure 1.

Problem 1 was about the water level. The left picture shows about half a glass of water. In the right **10** picture, the students are asked to draw the correct water level in equal to the leftmost image. **10**

Problem 2, the students are asked to identify the pyramid-shaped webs shown on the left side. In *Problem 3*, the students are asked **10** to select one of the four selected drawings that are identical to the standard image on the left side. In *Problem 4*, the students are asked to select one of the four selected images representing the standard image on the left side. In *Problem 5 and 6*, the students are asked to draw the pictures showing the images as the results of the other side.

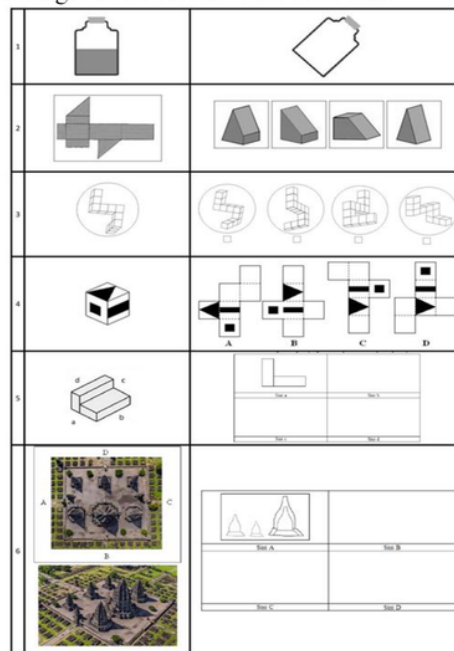


Figure 1. Spatial Ability Test

5. Results and Discussion

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This section will carry out the results and the discussion of research results based on the data obtained related to the students' spatial abilities based on differences in cognitive style and sex. This section will examine the similarities and differences in students' spatial performance.

5.1. Spatial Abilities of Male with Field Independent Cognitive Style

In spatial perception component, the subject determined the position of water surface by remembering and knowing that water was a liquid that fill the entire room so that the surface is always straight and horizontal. Although the container altered in any way, the surface of water will always remain straight.

In spatial visualization component, the subject determined the outcome of change or displacement part of the solid figures by looking at one by one all the parts of the webs and solid figures. Then, the subject matched the parts of the webs that same with the part of solid figures.

In mental rotation component, the subject determined the rotation result by imagining the rotation of solid figures in the appropriate direction. The subject imagined it without counting the number of cubes on the solid figures at first. The subject must ensure that the solid figure has the same direction

In spatial relation component, the subject determined which webs that can form a known solid figure by arranging the webs into solid figures. After that, the subject looked at the relation among the parts by matching the position or direction of each part of the webs and solid figures.

In spatial orientation component, the subject determined the shape of the figures when he viewed from different angles by considering the size of the drawing and the things drawn as seen from the specified sides.

5.2. Spatial Abilities of Male with Field Dependent Cognitive Style

In spatial perception component, the subject determined the position of water surface by remembering and knowing that water has flat surface following the shape of the container. However, the position of water depicted by the subject is still not quite right. Because the subject thought that if the place tilted, then the water level also tilted.

In the spatial visualization component, the subject determined the outcome of change or displacement part of the solid figures by looking at the shape and position of some parts of the webs and solid figures and matching those parts.

In mental rotation component, the subject determined the rotation result by imagining the rotation of solid figures in the appropriate direction. The subject imagined it with counting the number of cubes on the solid figures at first. After that, the subject rotated the image. Once rotated, he looked at the direction of the parts of the image whether it is the same as the known solid figures or not.

In spatial relation component, the subject determined which webs could form a known solid figure by arranging the webs into solid figures. After that, the subject looked at the relation among the parts by matching the position or direction of each part of the webs and solid figures.

In spatial orientation component, the subject determined the shape of the figures when viewed from different angles by imagining and drawing the visible portion of the specified side. The subject observed the position and size of the figures.

5.3. Spatial Abilities of Female with Field Independent Cognitive Style

In spatial perception component, the subject determined the position of water surface by remembering and knowing that water is a liquid that fill the entire room so that the surface is always straight and horizontal. Although the container altered in any way, the surface of water will always remain straight.

In spatial visualization component, the subject determined the outcome of change or displacement part of the solid figures by looking at one by one all the parts of the webs and solid figures. Then, the subject matched the parts of the webs that same with the part of solid figures.

In mental rotation component, the subject determined the rotation result by imagining the rotation of solid figures in the appropriate direction. The subject imagined it with counting the number of cubes on the solid figures at first. The subject must ensure that the solid figure has the same direction. She looked at the bend / curve whether is it the same as the known solid figures.

In spatial relation component, the subject determined which webs could form a known solid figure by looked at the relation among the parts by matching the position or direction of each part of the webs and solid figures. After that, she arranged the webs into solid figures.

In spatial orientation component, the subject determined the shape of the figures when viewed from different angles by imagining the figure if it is on that side and drawing it.

5.4. Spatial Abilities of Female with Field Dependent Cognitive Style

In spatial perception component, the subject determined the position of water surface by remembering and knowing water has flat surface following the shape of the container. However, the position of water depicted by the subject is still not quite right. Because the subject thought that if the place tilted then the water level also tilted.

In spatial visualization component, the subject determined the outcome of change or displacement part of the solid figures by making the same webs and arranging it into solid figures.

In mental rotation component, the subject determined the rotation result by counting the number of cubes on the solid figures at first. After that, the subject imagined it with standing on the adjusted side to form solid figures. The subject observed the direction per section of the solid figures that it had same direction with known solid figures.

In spatial relation component, the subject determined which webs could form a known solid figure by drawing the webs, after that she arranging the webs into solid figures. When she drew the webs, she noticed the shape, position and direction of the solid figures.

In spatial orientation component, the subject determined the shape of the figures when viewed from different angles by imagining to standing on the specified side, looking at the shape of the visible figures with respect to the size and position of the figures.

5.5. Similarities and Differences in Students' Spatial Abilities

5.5.1. *Similarities in Students' Spatial Abilities.* Based on the results of spatial ability tests and interviews on male FI & FD and female FI & FD obtained some things about the similarities between the male FI & FD and female FI & FD. Here are the similarities of spatial abilities of male FI & FD and female FI & FD.

- In the spatial perception component, the four subjects remembering and knowing that water is a liquid that filled the entire room so that the surface is straight and horizontal.
- In spatial orientation component, the subject determined the shape of the figures when viewed from different angles by considering the size of the drawing and drawn as seen from the specified sides.

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5.5.2. *Differences in Students' Spatial Abilities.* Based on the results of spatial ability tests and interviews, the researcher obtained some information that showed the differences in spatial ability between male subjects FI & FD and female FI & FD. Differences in sex indicate that the methods of problem solving done by the four subjects are also different. In accordance with the results of Zhu' study [12], it was found that that men and women showed different strategy choices used to obtain solutions. Besides sex, cognitive style differences also have an effect on solving a problem. This is in line with the opinions of Witkin, Moore, Goodenough, & Cox [13] that suggest that cognitive style differences affect a person's strategy of accepting, thinking, solving problems, learning, and connecting to others. Here are the differences in spatial abilities of male subjects FI & FD and female FI & FD.

Table 1. Differences in Students' Spatial Abilities

	FI MALE	FD MALE	FI FEMALE	FD FEMALE
Spatial Perception	The position of the water surface is flat, straight, horizontal	The position of the water surface is skewed	The position of the water surface is flat, straight, horizontal	The position of the water surface is skewed
Spatial Visualization	The subject matches all parts of the webs that same with the part of solid figures.	The subject matches some parts of the webs that same with the part of solid figures	The subject matches all parts of the webs that same with the part of solid figures	The subject creates a web and then folds it
Mental Rotation	The subject imagines the figure without counting the number of cubes on the solid figures at first.	The subject imagines it with counting the number of cubes on the solid figures at first.	The subject counts the number of cubes on the solid figures at first. After that, she matches bends or turns per section	The subject imagines counting the number of cubes on the solid figures at first. After that, she looks at objects from the other side
Spatial Relation	The subject arranges the webs into solid figures. After that, the subject looks at the relation among the parts by matching the position or direction of each part of the webs and solid figures.	The subject arranges the webs into solid figures. After that, the subject looks at the relation among the parts by matching the position or direction of each part of the webs and solid figures.	The subject looks at the relation among the parts by matching the position or direction of each part of the webs and solid figures. After that, the subject arranges the webs into solid figures.	The subject draws, cuts, arranges the webs into solid figures

6. Conclusion

Results showed that there are differences in the spatial abilities of the four subjects that are on the components of spatial visualization, mental rotation, and spatial relations. Meanwhile, in spatial perception and spatial orientation, the four subjects have the same spatial ability. The results showed that there are some differences done by the four subjects about the methods used to solve the problem. In terms of the sex differences, male students imagined the figures yet female students needed the media to solve the problem. Besides sex, cognitive style differences also have an effect on solving a problem. FI students were not affected by distracting information, while FD students can be affected by distracting information.

7. Acknowledgments

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