Jurnal Pendidikan Indonesia
Volume 13, Number 3, 2024 pp. 436-448
P-ISSN: 2303-288X E-ISSN: 2541-7207
Open Access: https://doi.org/10.23887/jpiundiksha.v13i3.77083

Analysis of Students' Spatial Ability in Geometry Material

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ARTICLE INFO

Article history:
Received April 03, 2024
Accepted July 19, 2024
Available online September 25, 2024

Kata Kunci:
Kemampuan Spasial, Gaya Kognitif, Field Independence, Field Dependence, Geometri.

Keywords:
Spatial Ability, Cognitive Style, Field Independence, Field Dependence, Geometry.

ABSTRAK

Penelitian ini menganalisis kemampuan spasial siswa berdasarkan gaya kognitif Field Independence (FI) dan Field Dependence (FD) dalam konteks pembelajaran geometri. Latar belakang penelitian adalah kesulitan yang sering dihadapi oleh siswa dengan gaya kognitif FD dalam memahami konsep-konsep geometri. Tujuan utama penelitian ini adalah membandingkan kemampuan spasial siswa FI dan FD serta mengidentifikasi faktor-faktor penyebab kesulitan siswa FD. Penelitian ini menggunakan pendekatan kualitatif dengan metode deskriptif. Subjek penelitian melibatkan 6 siswa, terdiri dari 3 siswa FI dan 3 siswa FD, yang dipilih menggunakan teknik purposive sampling berdasarkan hasil tes Group Embedded Figures Test (GEFT). Data dikumpulkan melalui wawancara, observasi, dan tes, kemudian dianalisis secara deskriptif kualitatif. Hasil penelitian menunjukkan bahwa siswa FI memiliki kemampuan spasial yang lebih unggul dibandingkan siswa FD, memenuhi indikator-indikator persepsi spasial, visualisasi, rotasi mental, hubungan spasial, dan orientasi spasial. Sebaliknya, siswa FD mengalami kesulitan dalam memenuhi sebagian besar indikator tersebut. Faktor-faktor yang berkontribusi terhadap kesulitan siswa FD meliputi ketergantungan pada lingkungan, kurang percaya diri, dan pemahaman yang kurang tentang materi prasyarat. Penelitian ini memberikan implikasi penting bagi strategi pembelajaran yang lebih efektif dalam mengatasi kesulitan siswa dalam belajar geometri, khususnya dengan mempertimbangkan perbedaan gaya kognitif siswa.

ABSTRACT

This study analyzes students' spatial abilities based on Field Independence (FI) and Field Dependence (FD) cognitive styles in the context of geometry learning. The research background is a difficulty that is often faced by students with the FD cognitive style in understanding geometric concepts. The main purpose of this study is to compare the spatial abilities of FI and FD students and identify the factors that cause the difficulties of FD students. This study uses a qualitative approach with a descriptive method. The research subject involved 6 students, consisting of 3 FI students and 3 FD students, who were selected using a purposive sampling technique based on the results of the Group Embedded Figures Test (GEFT). Data were collected through interviews, observations, and tests, then analyzed in a qualitative descriptive manner. The results showed that FI students had superior spatial abilities compared to FD students, meeting the indicators of spatial perception, visualization, mental rotation, spatial relationships, and spatial orientation. In contrast, FD students have difficulty meeting most of these indicators. Factors that contribute to FD students' difficulties include dependence on the environment, lack of self-confidence, and lack of understanding of prerequisite materials. This study provides important implications for more effective learning strategies in overcoming students' difficulties in learning geometry, especially by considering the differences in students' cognitive styles.

1. INTRODUCTION

Mathematics plays an important role in advancing human thought, developing critical, creative, systematic, and logical thinking (Jawad, 2022; Khan & Salman, 2020; Maslihah et al., 2020). Geometry is the branch of mathematics that is closest to our lives but is also considered difficult to learn. Geometry requires high-level thinking and visualization skills due to its abstract nature. Therefore, students often

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find it difficult to learn. Because of its abstract nature, one must have a good understanding and reasoning of geometric concepts. This understanding of concepts can be provided through events that occur around us or concrete objects as intermediaries or visualizations according to the level of understanding of the students. Because each person reaches abstract concepts through different learning levels (Darwina et al., 2022; Juman et al., 2022; Muftirah et al., 2023; Pauji et al., 2023). Our minds have a special skill for thinking about objects and space, known as spatial ability. This skill lets us imagine these objects and how their parts fit together, even picturing how they relate to things around them (Gonzales et al., 2020; Sweeney et al., 2014). In different sources, spatial ability refers to the capacity for representing, altering, generating, and recollecting symbolic, non-verbal data, characterized by two primary human spatial faculties: visualization and orientation (Gonzales et al., 2020; Langlois, 2020). Additionally, spatial ability is the mental manipulation of objects and their parts in 2D and 3D space (Cho & Suh, 2019, 2022). Thus, it can be concluded that spatial ability is the ability of someone's mind to visualize 2D and 3D images from different angles accurately. Spatial ability is closely related to spatial concepts, especially in geometry material (Goswami et al., 2021; Pastor et al., 2022). Spatial ability can be improved by studying geometry and conversely spatial ability can help understand geometric concepts. With spatial ability, students can solve mathematical problems (Aini et al., 2019; As'ari & Kusaeri, 2024). There are five components of spatial ability, namely Spatial Perception (someone's ability to identify vertical and horizontal objects even though the position of the object is manipulated), Spatial Visualization (the ability to visualize a configuration where there is movement or movement between parts (internal) configuration, Mental Rotation (someone's ability to quickly and accurately determine the result of a rotation of a 2 or 3 dimensional image), Spatial Relation (someone's ability to recognize the spatial configuration of an object or part of an object and the relationship between one another), and Spatial Orientation (someone's ability to orient themselves physically or mentally in space) (Dilling & Vogler, 2021; Medina Herrera et al., 2019). Difficulties in learning geometry are influenced by how someone learns, receives information, and solves problems. They have a unique way of learning in receiving the information that enters their minds because basically each individual has unique characteristics that distinguish one individual from another. One of the dimensions of individual differences, which is seen from the characteristics of students in responding, processing, storing, thinking, and using information to respond to a task or respond to various types of environmental situations is called cognitive style (Farmaki et al., 2019; Galiakberova & Galyamova, 2019; Kunxue, 2021).

This research is based on cognitive style because cognitive style affects students' thinking ability in solving problems. Cognitive style divides into two parts based on the difference in psychological aspects, namely Field Independence (FI) and Field Dependence (FD). The fundamental difference between these two cognitive styles is the extent to which a person is influenced by the environment or by the information given in solving problems. FI students have behavior that is not influenced by the environment. They tend to prefer to learn individually, solve problems independently, prioritize analytical and systematic thinking skills, are not too influenced by input/suggestions from others, and rely on internal motivation. However, it is difficult to master social sciences. Whereas FD students prioritize environmental influences, are more open to input/suggestions from others, tend to focus on the general picture, accept existing information, but can work well together because they have a social orientation. They have a high interest in social sciences. However, they have difficulty solving problems on their own. So they need help and prioritize external motivation (Farmaki et al., 2019; Nori et al., 2023; Sutama et al., 2021; Witkin et al., 1977). Based on the research conducted by previous research, a study on the spatial abilities of high school students was carried out (Ena et al., 2023; Muhammad et al., 2022). The results showed that urban students, particularly those from private schools, exhibited better spatial abilities compared to their rural counterparts. Another similar study by previous research focused on gender differences and mathematical problem-solving abilities (Lubienski et al., 2021; Ramírez-Uclés & Ramírez-Uclés, 2020). It concluded that gender did not significantly affect the types of errors or overall performance based on geometric properties. Both studies did not approach the cognitive styles of the students. Similar researched the academic achievements of prospective physics teachers based on their FI and FD cognitive styles (Busyairi et al., 2022; Junita et al., 2024). The results indicated that students with an FI cognitive style performed better academically than those with an FD cognitive style. This study focused on prospective physics teachers and general academic performance, whereas the planned research will focus on students in the specific context of spatial abilities in geometry. Therefore, it is necessary to conduct a specific study on the analysis of students' spatial abilities based on FI and FD cognitive styles in geometry to enhance individual understanding, develop creative thinking, and formulate effective learning strategies (Galiakberova & Galyamova, 2019; Jagom et al., 2020; Rahmah et al., 2019; Sudirman et al., 2020; Sumilat et al., 2019).

The novelty of this study is that this study focuses on an in-depth exploration of students' spatial abilities in geometry materials, which are still rarely comprehensively researched in the academic literature. This research aims to study the influence of students' cognitive style on their spatial ability in solving geometry problems, such as spatial perception, spatial visualization, mental rotation, spatial relation, and spatial orientation. It also discusses the factors that affect spatial ability. Based on the results of the initial spatial ability test conducted by 4 researchers on three-dimensional geometry material, there were several students who had difficulty fulfilling the spatial ability indicators. One of them has not yet fulfilled the indicators of spatial visualization, spatial perception, spatial relation, and mental rotation. In addition to the problems above, the researcher also obtained information from one of the mathematics teachers at the school that some students still have difficulty imagining something that is not real. Some students have difficulty connecting three-dimensional concepts with related formulas. Students who are not yet able to imagine spatial concepts will result in errors in using related formulas in problems. The difficulties experienced by students will have an impact on the mastery of geometry material itself and on other concepts in mathematics. Therefore, the researcher conducted a study with the title "Analysis of Students' Spatial Ability in Geometry Material." The expectation of this research is to identify the specific cognitive styles and spatial difficulties students face so that effective teaching strategies can be developed to enhance students' spatial abilities and overall performance in geometry.

2. METHOD

This research was conducted at a high school during the odd semester of the 2021/2022 school year. The research used a descriptive approach with a qualitative research type. The research technique is purposive sampling. The stages of this research are: (1) pre-field stage; (2) field work stage; and (3) data analysis stage. The research subjects are twelfth-grade students who have studied three-dimensional geometry material. After the subject selection test is carried out, 6 subjects will be selected from the 35 twelfth-grade students: 3 students with the FI cognitive style who had the highest GEFT scores and 3 students with the FD cognitive style who had the lowest GEFT scores. The selected subjects are then given a spatial ability test sheet and an interview. At the field work stage, it began with the selection of subjects by giving a cognitive style test in the form of the GEFT (Group Embeded Figure Test) test developed. This test is used to measure a person's ability to find a simple shape hidden in a complex pattern. The test consists of three parts, namely the first part consists of 7 pictures as practice (the results are not counted), the second and third parts each consist of 9 pictures which are the real tests. The allocation of time to work on the first part is 2 minutes. The second and third parts are 9.5 minutes each. Correct answers are given a score of 1 and wrong answers are given a score of 0, so the maximum score is 18. Subjects with scores of 0-9 are categorized as Field Dependence (FD) subjects and subjects with scores of 10-18 are categorized as Field Independence (FI) subjects (Mawla & Nurcahyo, 2024; Nailake et al., 2023).

The spatial ability test in this study aims to determine the subject's spatial ability based on the predetermined indicators presented in Table 1. This spatial ability test is a multiple choice test using the Three-Tier Multiple Choice technique. This technique has three levels, namely at the first level is a multiple choice question to ask students' knowledge of the problem, the second level is the reason for choosing the answer at the first level so that students' reasoning can be seen, and the third level is the level of students' confidence in answering the first and second levels (Julaeha et al., 2020; Rahmania et al., 2023). Tests with this technique are used to identify and measure students' spatial abilities whether they understand the concept, do not understand the concept or misconception of the material that has been studied, and can determine which part of the material needs to be emphasized and can plan a better learning model to help reduce misconceptions and improve learning ability. The guidelines for the test with this technique are in Table 2.

Before the test is given to the research subjects, the test is validated by two mathematics experts. Then it was tested on students from other classes who had studied geometry material, especially three dimensions. Then the data from the pilot test is analyzed to determine the validity, reliability, decoys, difficulty level, and item discrimination power with the help of SPSS Version 25.0 and Microsoft Excel 2007 programs. Furthermore, if the spatial ability test instrument is feasible, then the test can be given to the research subjects. Then continued with an unstructured interview with the aim of knowing the description of students' spatial abilities. The students who will be interviewed are subjects who have been determined as research subjects based on considerations of cognitive style tests, suggestions from mathematics teachers, and adjusted according to research needs. Before conducting the interview, the interview guidelines were validated by two mathematics experts. There are three criteria that will be assessed, namely the assessment of the material/content of the interview, the construction of the interview and the language of the interview. The credibility of the data in this study was tested with triangulation of sources and triangulation of techniques. After the data is collected, the researcher conducts an in-depth analysis.

Table 1. Spatial Ability Indicators

No	Indicators	Measured Capabilities	Description
1	Spatial Perception	Observing an object or its parts	Identifying spatial figures placed in horizontal or vertical positions from different perspectives
2	Spatial Visualization	Determining the composition of an object after its position and shape have been manipulated	Visualizing the actual shape of a spatial figure and determining the position of its faces after its position and shape have been manipulated
3	Mental Rotation	Rotating an object	Identifying the vertices and distances between points on a spatial figure after it has been rotated
4	Spatial Relation	Determining the relationship between objects	Determining the distance between a point and a line in space
5	Spatial Orientation	Determining an object from a particular point of view	Visualizing a spatial figure from a particular point of view

Table 2. Guidelines for Interpreting Results of Spatial Ability Tests Using the Three-Tier Multiple Choice Techniques

Question Difficulty Analysis	Answer Type			Category
	First Level	Second Level	Third Level	
Three-Tier Multiple Choice Question	Correct Answer	Correct reason	High	Understands the Concept
	Correct Answer	Correct reason	Low	Do not understand the concept
	Incorrect Answer	Correct reason	Low	
	Correct Answer	Incorrect reason	Low	
	Incorrect Answer	Incorrect reason	Low	
	Incorrect Answer	Correct reason	High	Misconception
	Incorrect Answer	Incorrect reason	High	
	Correct Answer	Incorrect reason	High	

3. RESULT AND DISCUSSION

Result

Based on the results of the subject selection test using the GEFT test, 6 subjects were selected from the 35 twelfth-grade students: 3 students with the FI cognitive style who had the highest GEFT scores and 3 students with the FD cognitive style who had the lowest GEFT scores. The results are presented in Table 3.

Table 3. Subject Coding for Research

No	Name	Score	Cognitive Styles	Subject Codes
1	S23	16	FI	SFI-1
2	S34	16	FI	SFI-2
3	S16	15	FI	SFI-3
4	S5	5	FD	SFD-1
5	S26	4	FD	SFD-2
6	S35	4	FD	SFD-3

Annotation:
SFI = Subject Field Independence
SFD = Subject Field Dependence

The selected research subjects were then asked to take a written test to assess their spatial abilities, followed by an individual interview with each subject. Before administering the test and interview, the instruments were validated by a validator. Item analysis was then conducted. Table 4 describes the instrument test analysis summary, which indicates that the instruments can be used as test items for assessing spatial ability in the research class. The results of the test and the results of the student interviews served as the data for analysis in this study.

Table 4. Instrument Test Analysis Summary

Question Number	Validity Test	Reliability	Difficulty Level	Discriminating Power	Distractor	Remarks
1	Moderate Validity	High	Moderate	Good	Functioning Well	Used
2	High Validity	High	Moderate	Good	Functioning Well	Used
3	High Validity	High	Moderate	Good	Functioning Well	Used
4	High Validity	High	Moderate	Good	Functioning Well	Used
5	High Validity	High	Moderate	Good	Functioning Well	Used

Based on Table 5, all three FI subjects successfully identified what was known and what was being asked, demonstrating an understanding of the given problem. Additionally, one FD subject was able to solve the spatial visualization problem presented. Subjects were able to provide complete explanations during the interview. It is evident from the answers and reasons given that the subjects were able to gather information based on what was known in the problem, thus enabling them to answer correctly. This is in line with the opinion of previous research stated that FI students are more skilled in reorganizing information (Siahaan et al., 2019; Wulan & Anggraini, 2019). Then the subjects were also able to imagine the actual shape of a structure, namely a cardboard net whose actual shape is a cuboid.

Table 5. Final Test Results by Research Subject

Subjects	Spatial Ability Indicators				
	Spatial Visualization	Spatial Relation	Spatial Perception	Mental Rotation	Spatial Orientation
SFI-1	√	√	√	√	√
SFI-2	√	√	√	√	√
SFI-3	√	√	√	√	√
SFD-1	√	-	-	-	-
SFD-2	-	-	-	-	-
SFD-3	-	-	-	-	-

Annotation:
(√) = Meets the spatial ability indicator
(-) = Does not meet the spatial ability indicator

On the Spatial Visualization indicator, SFI-1, SFI-2, SFI-3, and SFD-1 were able to meet this indicator. The subjects is able to plan steps to solve a given problem. The four subjects were able to determine the result of the movement or displacement of parts of a structure into a whole form by looking at all parts that have the same shape and size and then folding them so that a cuboid is formed. The subjects were then asked to determine a plane that intersects with another plane after knowing the actual shape of the structure. It can be seen that the four subjects were able to determine a plane that intersects with another plane along with its common line. The subjects were also able to distinguish between planes that are parallel or intersecting. On the Spatial Relation indicator, SFI-1, SFI-2, and SFI-3 were able to meet this indicator. In receiving problem information, they used a strategy that was not much different, which was to draw the object first to make it easier to understand the problem. The subjects were able to recognize the parts of the object and the relationship between them. It can be proven that the three subjects were able to determine the distance from a point to a line in space correctly. The subjects knew that there was a relationship between point E and line CD, so they obtained the length of line segment ED, which is the shortest distance from point E to line CD. The subjects were also able to identify and connect the concepts in the object with their prior knowledge. It can be proven that to calculate the length of ED, the three subjects connected it with the concept of the Pythagorean Theorem. This is in line with similar research, who explains that students with the FI cognitive style are able to connect the given problem with the material that has been learned, solve the problem according to the procedure, and are also able to connect it to other subjects (Izzatin et al., 2020; Wuryanie et al., 2020). On the Spatial Perception indicator, SFI-1, SFI-2, and SFI-3 were able to meet this indicator. The three FI subjects were able to understand the problem information well. The strategies they used were not much different. The three FI subjects imagined one by one the cereal boxes being put into the cardboard box with their longest edge in a horizontal and vertical position while counting their number. Unlike SFI-1, the other two subjects, SFI-2 and SFI-3, poured their imagination into a picture form so that it would not be difficult when imagining one by one the cereal boxes in the cardboard box. This shows that FI subjects are able to identify objects or spatial structures relative to a horizontal or vertical reference from a different perspective in their own way. On the Mental Rotation indicator, SFI-1, SFI-2, and SFI-3 were able to meet this indicator. The three FI subjects were able to rotate the block 90 degrees clockwise and place the corner points of the block accurately. The three FI subjects also understood the concept of the frontal plane as a reference. SFI-1, SFI-2, and SFI-3 were also able to determine the distance from a point to the intersection of the diagonals of the base of the block after it was rotated by remembering the concept of distance from point to point in space and the concept of the Pythagorean Theorem. This shows that FI subjects are able to determine the corner points and distance from point to point on a spatial structure after it is rotated. On the Spatial Orientation indicator, SFI-1, SFI-2, and SFI-3 were able to meet this indicator. All three FI subjects were able to observe the cube and its parts. The subjects were able to observe the position of the two black lines in the cube from a specified side by imagining it if they were on that side. Each FI subject knew that if the two black lines were extended, they would not intersect. The subjects had their own way of imagining the correct position. The FI subjects also knew that the position of the two black lines AF and BH were on different planes, but SFI-2 had a little difficulty explaining the position of the black line BH because it was in the middle of the cube. However, all three FI subjects were able to imagine the position of the lines from a specified side accurately. This shows that all three FI subjects were able to imagine spatial figures from a particular point of view.

Subjects with Field Dependence (SFD-1, SFD-2, and SFD-3) do not fully meet the indicators of spatial ability. Only SFD-1 has met the Spatial Visualization indicator. SFD-1 is able to visualize the actual shape of a three-dimensional object and determine the position of planes and faces after their position and shape have been manipulated. SFD-1 is also able to show the line of intersection resulting from the intersection of the two planes. SFD-2 and SFD-3 have not met the Spatial Visualization indicator. Both subjects made mistakes in visualizing the actual shape of the object. They did not understand the problem given when processing information from the problem because the shape of the object formed did not match what was known in the problem. SFD-2 and SFD-3 were misled to choose an image because they were based on two intersecting planes. However, during the interview, the subjects did not fully understand the definition of the line of intersection, so they also gave incorrect answers. This indicates that SFD-2 and SFD-3 are not yet fully able to visualize the actual shape of a three-dimensional object and determine the position of planes and faces after their position and shape have been manipulated. This is opinion that FD subjects think globally and their perception is easily influenced by manipulation of the surrounding situation.

SFD-1, SFD-2, and SFD-3 did not meet the Spatial Relation indicator. SFD-1 incorrectly perceived the relationship between a point and a line. SFD-1 had a misconception about the distance between a point and a line and guessed its value. Meanwhile, SFD-2 continued to use the wrong geometric shape, namely a cube, but realized that each edge was not the same length. SFD-2 used the formula for the diagonal of a cube to determine the distance between a point and a line in space. The error in number 1 would also affect the subsequent numbers. In SFD-3, it appeared that the answer to question number 2 was not filled in. SFD-3 experienced an inability to see the relationship between a point and a line. Based on the explanation above, SFD-1, SFD-2, and SFD-3 have not mastered the concept of distance between a point and a line based on the given problems. This is because the FD subjects have not mastered the prerequisite material or the basics of learning the material. This indicates that the three FD subjects are not yet able to identify and understand the relationships between the parts of an object correctly. According to previous research, FD subjects cannot utilize prerequisite knowledge to solve problems in various mathematical contexts. In addition, FD subjects are still unable to use the steps to solve problems, so they have difficulty determining the next steps and calculations (Abdara, 2017; Wakit & Hidayati, 2020). SFD-1, SFD-2, and SFD-3 did not meet the Spatial Perception indicator. The strategy used by the FD subjects was to first calculate the number of cereal boxes that could fit into the box and then imagine their position. SFD-1 used the same formula as in a similar problem that had been encountered in junior high school before. The formula is Volume of box : Volume of cereal box. Meanwhile, SFD-2 and SFD-3 calculated by dividing each dimension of the length, width, and height of the box by the dimensions of the cereal box one by one. The calculation results were correct. However, the three FD subjects were not yet able to imagine well the position of the cereal boxes in the box based on their longest edge. The three FD subjects were only able to identify that the cereal boxes were in a vertical position, as they commonly encountered. When solving the problem, both FI and FD subjects tried to use strategies that they considered appropriate. The difference is that FD subjects tend to solve problems only in the way that the teacher has shown before and rely on the vertical position of the boxes as is generally the case. This is in line with the opinion of similar research which states that individuals with the FD cognitive style are highly influenced by the environment or are dependent on the environment (Satriani, 2020; Silvester, 2019). Meanwhile, individuals with the FI cognitive style are not easily influenced by the environment or are not dependent on the environment. FD subjects solve problems by following the information that already exists. They have difficulty solving non-routine problems. This shows that FD subjects are dependent on their environment. Therefore, the researchers did not see any ability for FD subjects to identify an object in relation to a horizontal or vertical reference from a different perspective.

SFD-1, SFD-2, and SFD-3 did not meet the Mental Rotation indicator. The three FD subjects had difficulty imagining the rotation of geometric shapes, did not understand the concept of the frontal plane, and could not determine the distance of a point to the intersection of the diagonals of the base of the shape. Unlike the other subjects, SFD-1 only rotated the base of the block, not the entire shape. However, the rotation was still incorrect. They did not focus on the length of the sides of the block. These errors resulted in an incorrect determination of the distance of a point to the intersection of the diagonals of the base of the block. Based on this explanation, it shows that the three FD subjects were not able to determine the corner points of the block after it was rotated and were not able to determine the distance of a point to the intersection of the diagonals of the base of the block after it was rotated. The three FD subjects did not understand the information in the question and did not understand the basic concepts of mathematics. They need further guidance in solving mathematical problems like the one on the test. This is in line with previous research opinion that students with the FD cognitive style have the characteristic of needing clearer instructions on how to solve problems (Ningrum & Rahaju, 2023; Usmiyatun et al., 2021). In contrast, FI subjects are more able to solve problems without explicit instruction or guidance. Based on the answers, the field independent subjects, SFI-1, SFI-2, and SFI-3, were better able to translate the information in the question into a drawing and were able to imagine the rotation of a shape accurately than the field dependent subjects. This is in line with the findings of similar research which stated that FI subjects are able to represent the conditions of a mathematical problem by illustrating it in detail in a drawing, while FD subjects still have difficulty illustrating it (Astuti et al., 2023; Santoso et al., 2022).

SFD-1, SFD-2, and SFD-3 did not meet the Spatial Orientation indicator. The three FD subjects were mistaken in observing the location and position of two black lines from the specified side. SFD-1 was able to see that the two lines did not intersect. However, SFD-1's chosen answer was still wrong. Meanwhile, SFD-2 and SFD-3 said that the two lines intersected. The three FD subjects felt unsure of their own answers because they had difficulty imagining the correct position. In fact, SFD-3 even asked the researcher if their answer was right or wrong. This shows that the three FD subjects were not able to imagine the position of lines in a geometric shape as seen from a particular perspective. FD subjects were still hesitant and asked the researcher if their answers were right or wrong. In contrast, FI subjects felt confident in their answers. Someone with the FI cognitive style is a person with the characteristics of prioritizing motivation from within themselves (intrinsic motivation), being able to analyze objects separately from their environment, being able to organize objects, and having an impersonal orientation. In contrast, someone with the FD cognitive style is a person who tends to prioritize external motivation, thinks globally, accepts existing structures or information, and has a social orientation.

Based on the research results above, it can be seen that students with the FI cognitive style can meet all indicators of spatial ability. Meanwhile, students with the FD cognitive style only meet some indicators of spatial ability. SFD-1 only met the spatial visualization indicator, while SFD-2 and SFD-3 did not meet all indicators of spatial ability. This is in line with similar opinion that individuals with the same cognitive style do not necessarily have the same abilities (Purnomo et al., 2021; Usmiyatun et al., 2021). Moreover, individuals with different cognitive styles are more likely to have different abilities. Based on the research findings, there are some similarities and differences in the spatial abilities of FI and FD subjects. These can be seen in Table 6.

Table 6. Similarities and Differences in the Spatial Abilities of FI and FD Subjects

Similarities	Differences
Receiving information in the same way, namely by reading carefully. Using previously understood mathematical concepts and formulas.	Strategies or methods used by each subject in the information processing process to solve the problems for each indicator.

The research also found that there were problems with students' spatial abilities. The internal factors that caused these problems originated from the students themselves. The causes of these spatial ability problems tended to occur in students with the field dependence cognitive style. This can be seen in Table 7.

Table 7. Factors Causing Spatial Ability Problems in Field Dependent Students

Indicators	Contributing Factors		
	SFD-1	SFD-2	SFD-3
Spatial Perception	Relying on the available information	Relying on the available information	Relying on the available information
Spatial Visualization	-	Easily influenced/misled	Easily influenced/misled
Mental Rotation	Careless, lacking understanding of prerequisite material, and unable to illustrate drawings	Careless, lacking understanding of prerequisite material, and unable to illustrate drawings	Careless, lacking understanding of prerequisite material, and unable to illustrate drawings
Spatial Relation	Misconception and lack of understanding of prerequisite material	Misconception and lack of understanding of prerequisite material	Don't understand the concept and lack of understanding of prerequisite material
Spatial Orientation	Unsure	Unsure	Unsure

The internal factors that caused these problems were the students' cognitive styles, which tended to be more dependent on the environment and worked better when given help. This is generally related to the students' cognitive ability factors. In the process of solving problems, FD subjects were less careful in writing down their answers, lacked basic knowledge or prerequisite material for three-dimensional geometry, and experienced conceptual errors due to misconceptions that occurred when students received explanations from teachers during the online learning process. Based on the information obtained by the researchers, the first meeting for three-dimensional material at the school was still implementing online learning. Some students felt difficulties and were more comfortable if they were guided directly. FD subjects also tended to rely on the information that was available and the methods that were demonstrated by the teacher. In contrast, FI subjects used methods that were in accordance with the information provided in the questions and did not always rely on the methods that were demonstrated by the teacher. This is in line with the opinion of similar research which states that individuals with the FD cognitive style are highly influenced by the environment or are dependent on the environment, while FI individuals are less influenced by the environment (Kozhevnikov et al., 2014; Mertayasa et al., 2021). FI subjects tend to process their own information and prioritize intrinsic motivation (Fishbach & Woolley, 2022; Shin & Grant, 2019). FD subjects had difficulty solving non-routine problems, especially in three-dimensional geometry material where each problem varied. This is because learning geometry requires high-level thinking and visualization (Anwar et al., 2022; Wijaya et al., 2019). The FD subjects' dependence on the environment was one of the causes of misconceptions or problems (Linawati et al., 2022; Rusdianti & Masriyah, 2021).

Discussion

This research aimed to understand how a student's cognitive style, categorized as either Field Independent (FI) or Field Dependent (FD), affects their spatial abilities. The researchers conducted a series of tests measuring spatial perception, visualization, mental rotation, spatial relations, and orientation. The results showed a clear distinction between the two groups. Students with the FI cognitive style consistently outperformed their FD counterparts on all spatial ability tests. This can happen because students with an FD cognitive style tend to rely more on external factors and struggle with careless mistakes, foundational knowledge gaps, and misconceptions. Various studies can be discovered that are generally relevant and indirectly related to the findings of the study. According to previous research, FD subjects have difficulty applying their knowledge and solving problems in various mathematical contexts (Abdara, 2017; Wakit & Hidayati, 2020). Additionally, they struggle to determine the following steps and calculations required to solve problems. However, those with an FI cognitive style are able to connect the given problem with the material that has been learned, solve the problem according to the procedure, and are also able to connect it to other subjects (Izzatin et al., 2020; Wuryanie et al., 2020). Supporting this findings, research by similar research showed that FI students can effectively visualize math problems through detailed drawings. In contrast, FD students continue to struggle with this approach (Astuti et al., 2023; Santoso et al., 2022). Previous research added that FI students tend to do better in math because they can process information independently and handle complex problems (Hardi et al., 2023; Rofiki et al., 2020). They're comfortable in different learning environments and solve problems faster. On the other hand, FD students rely heavily on clear instructions and structured environments. They struggle with reorganizing information and may not be naturally drawn to math, leading to lower achievement. This suggests a strong link between cognitive style and a student's aptitude for spatial thinking.

These findings have significant implications for educators. By recognizing the influence of cognitive style on learning, teachers can adapt their instructional methods to cater to students with different learning preferences. When teaching students, one's cognitive style influences the cognitive strategies that work best in different situations. This is something that should be taken into consideration when planning teaching strategies and materials. The cognitive styles of students determine whether certain strategies and materials will improve or hinder students' achievement and learning (Dunlosky et al., 2013; Gustanti & Ayu, 2021). Similar research added that the interaction between cognitive style and teaching modes was significantly related to reaction time, indicating the importance of matching teaching modes with individual differences in future education (Yang & Chen, 2023; Zhang & Tian, 2019). For instance, students with the FD cognitive style, who tend to be more reliant on external cues and susceptible to misconceptions, might benefit from a more hands-on approach that incorporates visual aids and explicit instructions when tackling spatial concepts (Jia et al., 2023; Zhu et al., 2022). Conversely, FI students, who are more independent learners and process information intrinsically, might thrive in environments that encourage exploration and independent problem-solving (Mustafida & Jamaluddin, 2024; Nu'man & Maula, 2021).

The research was conducted on a relatively small sample size, potentially limiting the generalizability of the results to a broader population. This is a limitation of the current study. Additionally, the study design focused on establishing a correlation between cognitive style and spatial ability, which cannot definitively determine whether a student's cognitive style causes the difference in spatial abilities, or vice versa. Further research is needed to explore this potential cause-and-effect relationship. Based on these limitations, future studies should consider using larger sample sizes to improve the generalizability of the findings. Additionally, experimental designs that can establish causality should be employed to determine the direction of the relationship between cognitive styles and spatial abilities. The current study highlights the potential influence of cognitive styles on spatial reasoning, yet it leaves unexplored the possibility of improvement for students with either style. To address this, targeted interventions designed to meet each group's specific needs could be developed and tested to enhance their spatial skills. Furthermore, expanding the scope of research to investigate how cognitive styles impact learning outcomes in other subjects beyond spatial reasoning would provide a more comprehensive understanding of their effects.

4. CONCLUSION

Based on the research findings, it's clear that individuals with a Field Independence (FI) cognitive style excel in spatial abilities compared to those with a Field Dependence (FD) cognitive style. FI individuals consistently demonstrate strong skills in spatial perception, spatial visualization, mental rotation, spatial relation, and spatial orientation. They can easily identify, manipulate, and understand spatial figures from different angles. On the other hand, FD individuals struggle with these tasks. They often find it difficult to recognize spatial figures in various orientations, accurately visualize manipulated shapes, rotate figures correctly, and understand how parts of objects relate to each other. These difficulties in FD individuals are due to several internal factors, including susceptibility to external influences, misconceptions, lack of understanding of prerequisite material, dependence on their environment, carelessness in responses, challenges in drawing illustrations, and uncertainty in their answers. Overall, the study highlights a significant gap in spatial abilities between FI and FD cognitive styles. This suggests that addressing these internal factors through targeted interventions could improve spatial skills in FD individuals.

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