The Influence of Spatial Ability, Visual Thinking Ability, and Combinatorics Ability on Students Mathematical Problem Solving Ability

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Abstract. The aim of this research is to analyze: 1) the influence of spatial abilities, visual thinking abilities and combinatorics abilities on students' problem solving abilities simultaneously and 2) the influence of spatial abilities, visual thinking abilities and combinatorics abilities on students' partial problem solving abilities. The population in this study were class X students of private and public high schools in Medan in the 2022/2023 academic year. The research sample was 123 students taken from 4 schools in Medan with the criteria of one superior school and one ordinary school from private or state schools based on the results of the 2022 LTMPT UTBK survey. The research instrument is a description test of three abilities and multiple choice tests for spatial abilities. Prerequisite tests, multiple linear regression models, basic linear regression models, correlation analysis, and determinant coefficients are the data analysis approaches used in this study.

Keywords: Spatial Abilities, Visual Thinking Abilities, Combinatorics Abilities, Problem Solving Abilities.

1 Introduction

In life in this world, solving problems has become a fundamental activity for humans. The majority of human activities demonstrate this, notably resolving issues that come up in both the social and personal spheres. Schools as educational institutions have a very important role in developing the abilities and potential of students. Various lessons, especially mathematics, are presented to broaden your insight and hone your abilities so that you are better prepared to face problems in life. When faced with a challenge, students engage in mental exercises to comprehend the issue and then attempt to come up with a solution. In the process of creating a problem solving plan that has been prepared, students need to make new plans or come back to try to understand the problem better. So that in solving a problem students experience a process of improving their problem solving abilities, as well as other abilities that also accompany the learning process.

In addition to problem-solving skills, spatial abilities are crucial for resolving issues in daily life, the workplace, and educational settings. The capacity to conceptualize the transition of mental representations is known as spatial ability. The set of cognitive abilities known as "spatial thinking" is made up of three components: reasoning processes, representation tools,

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and spatial notions[1]. Spatial intelligence is one of the eight categories of human intellect (many intelligences) according to Hodward Gadner. The importance of spatial ability was also stated by Wai, et al where in-depth research shows that spatial ability and success in STEM (Science, Technology, Engineering and Mathematics) are strongly correlated. If students have good spatial abilities, they can easily participate in learning and solve problems well and easily. Likewise, if students' spatial abilities are low, they will have difficulty solving problems[2]. However, Indonesian students' average maths ability score is rated 34th out of 49 nations according to the 2019 Trends in International maths Science Study (TIMSS) report. Where the questions tested by TIMSS are geometry material which is closely related to spatial abilities[3]. Not only that, the results of a survey conducted by PISA in 2018 showed that Compared to the previous year, Indonesia saw a decrease, coming in at 73rd place out of 79 nations with an average score of 379[4].

Visual thinking skills also play a very important role in this matter. Not much different from spatial abilities, The capacity for problem-solving and understanding is known as visual thinking. Visualization can be a powerful cognitive tool in mathematical problem solving. With the use of visualization, students can recognize difficulties in a more straightforward manner, make connections and links, solve problems, formalize their grasp of the issue at hand, and recognize approaches applied to other problems that are comparable. Through visual thinking, problem solving can be obtained immediately, even without doing calculations. However, in reality students have not been able to use their visual abilities well in completing problem solving skills.

Apart from visual thinking abilities, according to several experts and researchers, combinatorics abilities also play an important role in problem solving abilities. Combinatorial thinking skills can support students' abilities in solving mathematical problems for students who have high, medium or low computing abilitiesCombinatorial thinking is a fundamental cognitive skill for handling issues in algebra, arithmetic, geometry, statistics, and other mathematical domains. Therefore, the ability to think combinatorially is a very important ability for students to have before studying several areas of mathematics such as geometry, statistics, algebra and arithmetic[5].

Drawing from the aforementioned reasoning, it is possible to conclude that developing students' spatial thinking, combinatorics, and spatial talents is crucial to improving their problem solving skills. In order to ensure that students stay up to date with current advancements and innovations, problem solving skills are crucial not just in the classroom but also in everyday life, particularly in the age of globalization and expanding modernity. It is crucial that we understand the extent to which these skills impact the ability to solve problems when learning mathematics. So that educators are able to maximize the ability to accompany and hone students

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in improving spatial abilities, visual thinking abilities and combinatorics abilities in an effort to improve problem solving abilities

2 Review Of Literature

2.1 Mathematical Spatial Ability

Spatial ability is a very important ability, both in everyday life and in the world of work. In everyday life it can be useful, such as erecting poles, installing photo frames on the wall so that they are perpendicular, predicting invisible dice, and making nets from spatial shapes. Professionals with skills like architecture, cartoon design, 3-dimensional animated films, and so on frequently use this spatial aptitude in their job.

Distance conversion (the ability to calculate the distance between two points), projective relationships (the ability to view objects from different perspectives), mental rotation (the ability to visualize an object rotating), and spatial relationships (the ability to notice the relationship between the position of objects in space) are all included in Piaget's abstract definition of spatial ability[6].

The ability to see, compare, estimate, ascertain, create, convey, and locate information from visual stimuli in a room setting is known as mathematical spatial ability. One can measure one's ability to: (1) state the distances between the components of a spatial structure; (2) recognize and categorize geometric images; (3) visualize the form or location of a geometric object when viewed from a particular angle; (4) create and present geometric models drawn on a flat plane in a spatial context; and (5) investigate a geometric object. After that, Maier in Prisnaini (2017) separates spatial talents into five categories: (1) Spatial Orientation; (2) Mental Rotation; (3) Spatial Relations; and (4) Spatial Perception[7].

The aforementioned experts' opinions lead us to the conclusion that spatial ability refers to a person's capacity to see, imagine, guess, identify the correct object, create, recall, and transform visual information about spatial objects, including drawing these objects on paper.

2.2. Visual Thinking Ability

According to Wileman, visual thinking is the capacity to convert any kind of information into pictures, graphics, or other formats that facilitate information communication[8]. The ability, process, and outcomes of creating, interpreting, using, and formulating ideas regarding pictures, drawings, and diagrams in the mind, on paper, or with the aid of technological tools, in order to describe and communicate data and concepts, advance earlier theories, and deepen comprehension, are also referred to as visual thinking[9]. Whether we like to

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admit it or not, visual thinking is a common part of daily life. For example, when someone asks for our address, sometimes we impulsively take out a piece of paper and a pencil to draw the address because it feels less difficult for us to follow directions and find the home address if there is a picture. Because it will be easier for someone to follow the instructions provided to find the location of the house if there are photos. Psychologists have considered visual thinking which they describe as a kind of non-verbal thinking.

Visualization plays a different function or role for students to solve problems. Presmeg explains that there are 7 roles of visualization, namely: 1) Students can comprehend the problem by seeing how its components relate to one another when it is visually presented to them. 2) Students can recognize the strategies applied to all of these difficulties by using visualization to make the challenges simpler. 3) to identify linkages (connections) to similar problems; these comprise related problems that were previously presented in encounters with problem resolution, 4) To understand each student's unique learning style, each one has a professional when it comes to applying visual aids and problem-solving techniques. 5) The solution to the issue can be found directly from the visual depiction itself, negating the necessity for computation or calculation. 6) Visual representations can be utilized as a technique for checking solutions, ensuring that the answers obtained are correct., 7) Mathematical forms can be obtained from visual representations in order to transform problems into mathematical form[10].

Bolton stated visual tinking steps can be seen from 4 stages, namely, (1) Looking, the focus at this stage is that students can identify issues or problems and look for relationships within them. Activities at this stage are students doing, viewing and collecting information; (2) Seeing, the focus in the seeing stage is that students can understand problems and find opportunities to solve problems. Activities in this stage are students carrying out selecting and grouping activities or analyzing activities; (3) Imagining, the focus at this stage is on students making solutions. Activities in this stage are students carrying out generalizing activities to find solutions, pattern recognition by solving problems; (4) Sowing and telling[11].

2.3. Combinatorics Ability

The ability to think combinatorially is a process of thinking both consciously and unconsciously related to the process of examining various information, feeling symptoms of patterns, feeling symptoms of similarities or differences between various objects, and trying to connect or connect these various patterns. Additionally, the foundation for solving issues in other areas of mathematics, including geometry, statistics, algebra, and arithmetic, is the capacity for combinatorial thought. Combining expressions or formulas, computation procedures, and outcomes or conclusions is known as combinatoric thinking. These three processes are interconnected and occur systematically[12].

The main factor in students mathematical thinking that is directly related to solving the problems used is the combinatorics thinking process. Several experts have revealed indicators in measuring students combinatorics abilities. Combinatoric thinking has four

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indicators, namely: (1)Understand the problems faced; (2) Find all possible cases; (3) Finding all possibilities systematically and (4) Changing the problem into another combinatorics problem[13][13]. Then, five indicators were created by modifying the combinatorial problem solving indicators: (1) What is known; (2) What you need to know; (3) Identifying difficulties; (4) Action Plan; and (5) Appropriate problem solving[14].

2.4. Problem solving skill

Children should be taught problem-solving skills from a young age. Every aspect of human endeavor, including in the fields of education, business, industry, science, health, literature, law, and so on, requires problem solving. Any discipline can teach problem solving, but it all comes down to arithmetic. solving problems is the most important aspect of mathematics education; without problem-solving skills, the application and potential of mathematical concepts, knowledge, and abilities are greatly limited.

The goal of issue solving is to arrive at a certain solution through a planned and executed process. Another viewpoint holds that problem solving is an endeavor to resolve an issue. The practice of applying one's knowledge, abilities, and comprehension to solve problems in circumstances they have never encountered is known as problem solving.

Indicators must be used as a point of reference for evaluation in order to gauge pupils' proficiency solving mathematical problems. Polya also mentions the problem-solving techniques contained in the book "How to Solve It". These phases are as follows: (1) Recognize the issue; (2) Formulate a plan for a solution; (3) Address the issue as planned; and (4) Verify the outcomes. NCTM also states four indicators of problem solving abilities namely: (1) Investigating and comprehending mathematical material; (2) utilizing a variety of mathematical problem-solving techniques; (3) identifying and formulating issues from the provided context; and (4) applying the application of mathematical models to actual circumstances [15].

3. Method

The goal of this research is to determine how students' spatial, visual thinking, and combinatorics skills affect their capacity to solve simultaneous and partial mathematical problems. This study employs a quantitative methodology and is an ex-post facto study, because it examines relationships that influence each other and is not manipulated or treated with the variables and data taken in this research after or while the incident is taking place. This research is directed at testing the influence of three variables, namely, spatial ability (X_1), visual thinking ability (X_2), combinatorics ability (X_3) on problem solving ability (Y).

This research was conducted at four high schools in Medan with two regular schools, namely SMA Negeri 14 Medan which is located on Jl. Student Gg. Darmo, District. Medan Denai, Medan City, then at SMA Methodist 12 Medan which is located on Jl. Panca No. 28,

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[13] M Rezaie & Gooya, Z. (2011). What Do I Mean by Combinatorial Thinking?. Procedia Social and Behavioral Sciences 11 (2011) 122-126.

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Harjosari II, Kec. Medan Amplas, Medan City and two superior schools, namely SMA Negeri 15 which is on Jl. Development School No. 7, Medan Sunggal, and SMA Santo Thomas 1 Medan which is located on JL. Lt. Gen. S. Parman No. 109, Central Petisah, District. Petisah Field. This study was conducted during the academic year 2022–2023 even semester.

The sample selection in this study used a cluster random sampling technique, where the population was divided into several groups. And in this study the population consisted of two private schools and two state schools at high school level in Medan which were taken with the criteria of 1 private or state superior school and 1 private and state ordinary school. Then the sample that the researcher took was class X from four schools. The instruments used in this research were descriptive and multiple choice tests. Prerequisite tests, multiple linear regression models, correlation analysis, and determinant coefficients are the data analysis methods applied in this study. This test uses SPSS 25.0

This research design connects variables and the dependent variable is students mathematical problem solving abilities (Y). The form of research design is as follows:

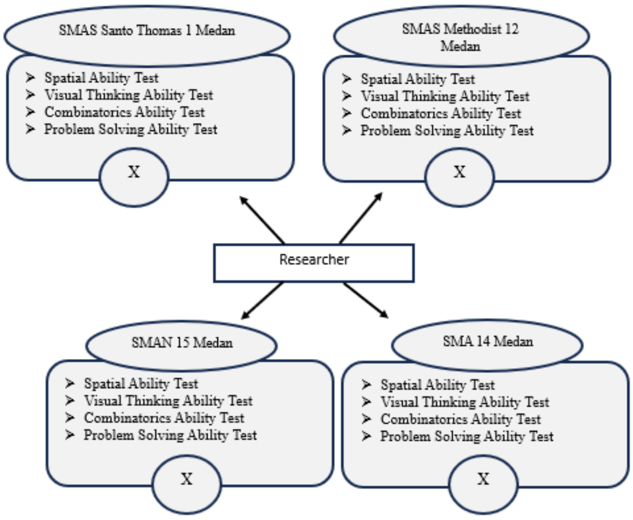

Fig. 3.1 Research Desig

4. Research Result

The resulting data is in the form of quantitative data. Through this research, a number of data will be obtained including: 1) spatial ability test results; 2) visual thinking ability test results; 3) combinatorics ability test results and 4) student problem solving ability test results. The data described in this research includes data from a spatial ability test (X1), a visual thinking ability test (X2), a combinatorics ability test (X3) and a student problem solving ability test (Y) taken from 123 public and private high school students in the city of Medan. The following table displays the results of the calculation:

Table 1. Summary of Results of Research Variable Values

Statistics	X1	X2	X3	Y
Lowest Value	100	95,83	93.75	93,75
The highest score	30	33,33	33,33	37,50
Mean	68,130	69,072	70,122	74,459
Std. Deviation	17,051	15,792	15,668	14,772

4.1 Multicollinearity Test

The presence of a relationship between the independent variable X in the multiple regression model is known as the multicollinearity test or double collinearity. When there is no intercorrelation between the independent variables (no signs of multicollinearity), the regression model is considered excellent. The Variance Inflation Factors (VIF) and collinearity tolerance levels are examined in this study's multicollinearity test using SPSS 26.0, and the following hypothesis is tested:

H_0 : there is no multicollinearity
Ha: there is multicollinearity
The test criteria are as follows:

- If VIF ≤ 10 and Tolerance value ≥ 0.10 then it can be concluded that there are no symptoms of multicollinearity between the independent variables
- If VIF ≥ 10 and Tolerance value ≤ 0.10 then it can be concluded that there are symptoms of multicollinearity between the independent variables

Table 2. Multicollinearity Test Results

Coefficientsa

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	T	Sig.	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	10.546	1.618		6.518	.000		
	Mathematical Spatial Ability	.113	.052	.130	2.154	.033	.154	6.493
	Visual Thinking Ability	.316	.059	.343	5.378	.000	.138	7.234
	combinatorics ability	.491	.061	.521	8.042	.000	.134	7.470

a. Dependent Variable: Problem Solving Ability

Based on the multicollinearity test's guidelines and the aforementioned table, it is evident that the VIF value is: 6.493; 7.234 and 7.470 are less than 10 respectively, so H_0 is accepted, namely there is no multicollinearity in this research data. This means that the independent variables mathematical literacy ability (X_1), critical thinking ability (X_2) and mathematical communication ability (X_3) do not interfere with each other's contributions.

4.2 Multiple Linear Regression Analysis

Based on the outcomes of the tests for mathematical literacy, critical thinking, mathematical communication, and student problem solving, the following computation results were derived using SPSS 26.0:

Table 3. Results of Multiple Regression Coefficient Calculation

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	10.467	1.661		6.300	.000
	Spatial_Ability	.153	.059	.177	2.609	.010
	Visual_Thinking_Ability	.267	.059	.285	4.531	.000
	Combinatorics_Ability	.501	.062	.531	8.138	.000
a. Dependent Variable: Problem_Solving_Ability						

Table 3 shows that the equation for the multiple linear regression model is $\hat{Y} = 10{,}467 + 0{,}153X_1 + 0{,}267X_2 + 0{,}501X_3$. From this equation, it means that if spatial ability (X1) increases by one unit and visual thinking ability and combinatorics ability are constant, then the student's problem solving ability (Y) will increase by 0.153 with a spatial ability of 10,467. Likewise, with visual thinking ability (X2) increasing by one unit and spatial ability and combinatorics ability being constant, students' problem solving ability (Y) will increase by 0.267 with students' visual thinking ability being 10,467. Then, if the combinatorics ability (X3) increases by one unit and the spatial ability and visual thinking ability, then the student's problem solving ability (Y) will increase by 0.501 with a combinatorics ability 10,467.

4.3 Correlation Analysis and Determinant Coefficients

The strength of the contribution of a variable to other variables can be determined using correlation analysis. Coefficient_Correlation and determinant coefficients can be searched simultaneously using SPSS 26.0 and The following table displays the results:

Table 4. Simultaneous Correlation Coefficient and Determinant Coefficient

Model Summary[b]									
					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.965[a]	.932	.930	3.89889	.932	544.127	3	119	.000
a. Predictors: (Constant),Spatial_Ability,Visual_Thinking_Ability,Combinatorics_Ability									
b. Dependent Variable: Problem_Solving									

The value is evident in the preceding table. The correlation coefficient (r) is 0.965, this proves that between visual thinking ability,.literacy abilities, spatial abilities and combinatorics abilities with solving abilities.the problem has a very strong attachment relationship. Subsequently, this research revealed that the Adjusted R Square value was 0.930, indicating

93% of the capacity for solvingVisual thinking, reading, spatial, and combinatorics skills all have an impact on the problem; the remaining 7% is influenced by other variables from the regression equation.

. Coefficient_Partial correlation and determinant coefficients can be searched using SPSS 26.0 and the following table displays the results:

Table 5. Correlation Coefficient and Partial Determinant Coefficient X_1 against Y

Model Summary[b]									
					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.923[a]	.851	.850	5.71815	.851	693.238	1	121	.000
a. Predictors: (Constant),Spatial_Ability									
b. Dependent Variable: Problem_Solving									

The correlation coefficient (r), which is 0.923 based on the aforementioned table, indicates that spatial aptitude and problem-solving ability have a very strong link. Then, the determinant coefficient (R2) is 0.850, indicating that spatial ability influences ability problem solving by 85% and other components in the regression equation by the remaining 15%.

Table 6. Correlation Coefficient and Partial Determinant Coefficient X_2 against Y

Model Summary[b]									
					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.925[a]	.856	.855	5.62268	.856	721.122	1	121	.000
a. Predictors: (Constant),Visual_Thinking_Ability									
b. Dependent Variable: Problem_Solving									

The correlation coefficient (r), which is 0.925 in the table above, indicates that there is a substantial association between problem-solving and literacy skills. The determining coefficient (R2), which has a value of 0.855, indicates that visual thinking skills impact 85.5% of problem solving abilities, with other factors in the regression equation influencing the remaining 14.5%.

Table 7. Correlation Coefficient and Partial Determinant Coefficient X_3 against Y

Model Summary[b]									
					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.950[a]	.903	.903	4.61198	.903	1130.663	1	121	.000
a. Predictors: (Constant),Combinatorics_Ability									
b. Dependent Variable: Problem_Solving									

The correlation coefficient (r), which is 0.950 in the table above, indicates that combinatorial skills and problem-solving skills have a very strong link. Then, 90.3% of the problem-solving ability is determined by combinatorics skills, and the remaining 9.7% is determined by other factors in the regression equation, according to the determinant coefficient (R2), which has a value of 0.903.

5. Discussion

The spatial ability test, visual thinking ability test, combinatorics ability test and student problem solving ability test have been distributed to 123 students taken from 4 junior high schools in the city of Medan, namely SMAS Santo Thomoas 1 Medan, SMAS Methodist 12 Medan, SMAN 15 Medan and SMAN 14 Medan. The study's findings led to the conclusion that students' simultaneous problem-solving skills were positively and significantly impacted by the factors of spatial ability, visual thinking capacity, and combinatorial ability.

According to the study's findings, mathematical skills are essential for all students to succeed in the information-rich, globalized world of today. All of these mathematical abilities are also stated in writing in the objectives of mathematics subjects in primary and secondary education as stated in the KTSP, 2013 curriculum and refined in the independent curriculum. Likewise, according to problem solving skills help students think analytically in making decisions in everyday life and help improve other mathematical abilities such as mathematical literacy skills, critical thinking skills and mathematical communication skills in dealing with new situations[16] [16].

6. Conclusion

The research data analysis results discussed in the preceding section allowed for the following conclusions to be drawn on the effects of spatial thinking, combinatorics, and visual thinking skills on problem solving abilities: There is an influence of spatial abilities, visual thinking abilities and combinatorics abilities on students' problem solving abilities Class X high school in Medan simultaneously. There is a partial influence of spatial abilities, visual thinking abilities and combinatorics abilities on the problem solving abilities of class VII high school students in Medan.

Level of relationship closenessspatial abilities, visual thinking abilities and combinatorics abilitieson the problem solving ability of classspatial abilities, visual thinking abilities and combinatorics abilitieshas an effect of 93% on simultaneous problem solving abilities. Meanwhile, 7% is determined by other variables.

Spatial thinking, visual thinking, and combinatorics skills have a favorable and considerable impact on pupils' capacity to partially answer issues in Medan. With a very strong association between spatial ability and problem-solving ability (0.923 and 0.850 for the determinant coefficient, R2), spatial ability influences problem-solving ability by 85%. Similarly, there is a very significant correlation between students' capacity to think visually and their ability to solve problems (0.925) and a determinant coefficient (R2) of 0.855. This indicates

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that 85.5% of students' problem-solving ability is influenced by their visual thinking skills. Lastly, there is a very substantial correlation between combinatorial ability and problem solving ability (r = 0.950, r = 0.903), meaning that 90.3% of problem solving ability is impacted by combinatorial ability.

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