Visual reasoning analysis of female students in solving mathematical problems

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Abstract. To solve the problem of mathematics, students need reasoning. Visualizations can help in reasoning. This paper discusses the results of visual reasoning analysis of female students in solving mathematical problems. The method of study used is a qualitative method with the subject of female students of the Mathematics Education Study Program of Universitas PGRI Madiun. Data is validated with time triangulation. Data that is natural, deep, and widespread are displayed and analyzed. The conclusion of the study is: 1) to solve mathematical problems, female students perform complex steps of completing Polya, namely: understanding problems with visualizations, planning a problem solving with mathematics, planning a problem solving with elimination/substitution, implementing a plan to solve problems with elimination/substitution, checking results, planning to solve problems with determinations, implementing plans to solve the problems with determinations, examine results, plan to solve problems with coordinate points, implement plans to solve problems with coordinate points, check the results of the sponsorship with the coordinate points; 2) every activity in resolving the problem, female students have done reasoning. However, not all activities are identified to perform visual reasoning. Students tend to still focus on formalities; 3) in the issue, the subject performs reasoning deductive or inductive and visualizes contextually or mathematically as needed.

1. Introduction

In Indonesian dictionary, reasoning comes from the word "reason" which is interpreted as a person's activity logical thinking. Reasoning is the process of thinking of linking known facts to a conclusion [1]. Reasoning is an activity of logical and analytical thinking in discovering a truth [2]. Reasoning indicates the occurrence of the processing of information occurring in the mental or mind to draw conclusions.

Reasoning is often in view as the construction and manipulation of mental models. Human reasoning relies on the construction and manipulation of mental models used as an explanation of knowledge [3]. Reasoning features include logical and analytical thinking according to [4]. Reasoning Indicators: 1) presenting a written mathematical statement and drawing, 2) conducting mathematical manipulation, 3) examining the validity of an argument, and 4) draws conclusions from the statement [5]. Based on the process, reasoning can be differentiated into two namely: deductive reasoning and inductive reasoning. Deductive reasoning is the process of reasoning that its context is derived absolutely by its premises. Inductive reasoning is the process of reasoning in obtaining a general conclusion based on empirical data.

Reasoning is a high level mathematically thinking skill. The most important thing about thinking...
is information processing. Information processing is a mind activity that is in the form of inserting, storing, and using information [6]. The mind pulls the information through scanning before further processing [7]. The information is processed as active information [8]. The processing, outgoing, and inclusion of information in memory are directed by the control processes (executive) or purpose in the form of a password. Explain that a password is an information unit of a modality. Encoding is an information transformation process in the information processing system [9]. There are three central theories of encoding, namely: the theory of Double-encoding (visual and verbal), the propositional-Conceptual theory (visual and verbal information is represented in the form of an abstract proposition), and the theory of equivalence-functional (System Imagery-Nonverbal and symbolic-verbal systems involve similar processes) [10].

Visual information called mental shading and processing of mental shading is called visual thought. Visual thinking for reasoning is called visual reasoning. Preliminary study shows that there are some problems still found in learning. Most students are still struggling in visual thinking because they are too focused on formalities [11]. Similarly, at university level, the wealth of mental shading of students in mathematics is very lacking [12, 13]. The ability to process visual information or visual thinking is helpful in solving or resolving problems.

Troubleshooting is a process that is used to resolve the problem. Get four stages of problem solving, namely: understand, plan solutions, execute plans, and check back [14]. A student if faced with a problem, in the end they are not merely solving problems, but also learning something new [15]. There are three problem solving models in Indonesia that are commonly applied in learning, namely: writing the known, asked, and answer/proof [16]. Problem-solving is studied since elementary school to university level.

Students are individuals who study in higher education levels. The characteristics of student learning behaviour that brings a lot of experience, less flexible in interacting, want to be treated according to the maturity, and have an initiative as well as self-reliant [17]. Students of mathematics teachers are students attending mathematics education courses. Learning Mathematics aims to organize reason, form attitudes, and foster mathematical skills [18]. Although with visual thinking, students solve problems according to the stages of Polya, namely: understand, plan, implement, and re-examine [19, 20]. However, the stages and weaknesses were detected in resolving the problem [21]. Análisis visual reasoning students in solving the mathematical problems have not been researched.

2. Methods
The research method used to analyse the visual reasoning of female students in solve mathematical problems is a qualitative research method. The research subject was chosen from the mathematics education course of Universitas PGRI Madiun. Activities for subject selection on the target class, among others: Choosing a class, registering students, determining the subject of the woman, assessing the test results and determining the research subject. Based on the data obtained indicates that the subject chosen in accordance with the provisions of the criteria is Padma Jati Hilmiyah who possesses high capability with NIM 15411087 and female gender.

The main instrument of this research is its own researchers. Assisted instrument development activities began from the study of libraries, the development of student work sheets, interview guidelines and protocols, and validated so that a valid auxiliary instrument is obtained. This activity result is a student task sheet with the following cores.

A company has one car of Mitsubishi, one Suzuki car, and one Daihatsu car used to distribute three types of food, namely: rice, noodles and cooking oil. The Mitsubishi car is capable of carrying 19 sacks of rice, 10 cardboard noodles and 24 pack of cooking oil. The Suzuki car is capable of carrying 6 sacks of rice, 4 cardboard noodles and 8 packs of cooking oil. The Daihatsu car is capable of carrying 11 sacks of rice, 6 cardboard noodles and 14 pack of cooking oil. The number of times the transport of each car Mitsubishi, Suzuki and
Daihatsu if the company distributes 100 sack of rice, 56 cardboard noodles, and 128 pack of cooking oil?

Student task sheets contain hints to guarantee in getting the data and get the subject's clarity in resolving the problem.

The student's assignment sheet after the next activity is composed of interview guidelines. The results of this activity are interview guidelines. The interview guidelines contain interview objectives, interview success indicators, interview design and the provision of interview questions. The purpose of the interview is to get visual reasoning profile data of students in resolving mathematical problems. The next activity is to arrange the interview guidelines and protocols as the previous trial results.

The next activity is to validate. The outcome of the activity validity of the auxiliary instrument is a valid instrument so that it can be used to collect data. The auxiliary instruments in this study are the test sheets of mathematical abilities, student task sheets, interview guidelines, and interview protocols.

3. Result and Discussion

As per the research method, interviews are conducted to obtain data that is natural, profound, and extensive. After the validation, reduction, and categorisation process, here's a summary profile of female student visual reasoning in solving the mathematical problems.

3.1. Step 1: Subjects understand problems with visualizations

After reading the given issue, the subject visualizes the problem given contextually. This is evident from the following interview results.

“... There are 3 types of cars, for each car there is a certain quota to transport goods, each car has different quota to transport goods... There are 3 different cars i.e. the first there is a Mitsubishi car, the second there is a Suzuki car and the third there is a Daihatsu car. Keep these three cars must distribute a number of goods that the car must distribute 67 sacks of rice, 17 cardboard noodles and 19 pack of cooking oil... Overall... The first Mitsubishi car can bring 19 sacks of rice, 10 packs of noodles and 24 pack of cooking oil, while the second car is the Suzuki car which can bring 6 sacks of rice, 4 cardboard noodles and 8 packs of cooking oil, the last one is the Daihatsu car capable Carrying 11 sacks of rice, 6 cardboard noodles and 14 pack of cooking oil...”

The subject reasoned inductive because the subject thinks that the existing premises are common. The decision to receive information based on the existing premise is the result of an inductive conclusion withdrawal process. The subject thinks visually in understanding the problem given. Since the problem is a contextual problem, the subject is also visualizing in visual form. The problem given is a visual input. This is because the subject has experience in the everyday life of Suzuki, Daihatsu, and Mitsubishi cars carrying rice, cardboard noodles, and cooking oil. These objects become mental imagery that is raised, processed, and utilized to understand the problem. The Output of this mental activity is an understanding of problems.

3.2. Step 2: Subjects plan to solve problems mathematically

The subject plans to solve the problem mathematically. It is indicated by the following field notes.
The subject explains what is known of the matter, the subject gives the description pointing

"If from this, from the three cars, for example the first car Mitsubishi must carry 19 sacks of rice, while the Suzuki 6 sack of rice and Daihatsu cars are able to carry 11 sacks of rice, but that should be transported there are 100 sacks of rice. How to make the three cars can fulfill the quota transported there are 100 sacks of rice.... The asked how many times the car distributes so if a car. To distribute the goods then the value must be positive so we use a condition: that where x, y and z it should be more than equal to zero"

This Data indicates that the subject has a plan to solve the problem given using mathematics. However, the problem given is not easy so the advanced plan is required to complete.

For this activity, the subject reasoned deductive. The subject reasoned deductively because based on an existing premise, the subject led to a mathematical form. The subject does not think visually because to bring the premises into the mathematical form does not involve a mental imagery. Thus, for this activity the subject does not neglect visual reasoning.

3.3. Step 3: Subject to planning with elimination/substitution

The subject plan solves the problem given using the elimination/substitution.

“If I think after we know these equations we can solve them by means of the element... ... Because it's easier to pack, remove the efficiency...., so that we know how many times each car is transporting or distributing the goods”

In addition to using elimination, some subjects also use a combined elimination-substitution. The elimination/substitution method is chosen because students master this method to solve many problems.

The results of this activity are the decision to use elimination/substitution. To obtain such a decision, the subject is inductive and deductive. The subject reasoned inductive because it considers that all problems can be solved by substitution/elimination. The subject reasoned in deductive due to the idea of raising the subject from previous experiences. The subject does not think visually because to do the elimination/substitution is only done according to procedural and does not involve a mental imagery. Thus, for this activity the subject does not neglect visual reasoning.

3.4. Step 4: Subject to implement plans to resolve problems with elimination/substitution

After having a plan to solve problems with elimination/substitution, subject carries out the plan. Here is a representation of the results.
The reason for the subject in the first step is

“... To eliminate the x, y, and z variables, this is easy and because usually if there is such a problem, the easiest way to do the elimination and the substitution...”

The Data shown indicates that the subject only uses elimination. However, in some questions, it turns out that the subject also sometimes uses substitutions.

Implementing a plan to use the elimination/substitution in resolving the problem given is a decision. To get the decision, the subject reasoned deductively. Subject reasoning can be categorized as deductive reasoning because decisions are taken according to common plans that are specifically operated. The subject does not involve a mental imagery for activity. The subject only operates in accordance with the elimination/substitution procedures. Therefore, for this activity, the subject does not perform visual reasoning.

3.5. Step 5: Subject checking results

After using the elimination, the subject gets a result \(0 = 0\) which does not have the meaning for the problem solving given. In addition to being shown by the field notes above, it is also evident from the interview results

“... But after the elimination of the results is eliminated zero... The result of completion is zero, cannot"

The subject feels unsuitable for the answers obtained.

The subject's assessment of its own answer is less suitable for the resolution of the problem given as a decision. The decision is taken based on the outcome of the activity re-examining the outcome with the given issue. Therefore, in this activity, the subject reasoned deductive. The subject does not involve a mental imagery for this activity. The subject only draws conclusions based on the test result as per the answer to the given problem. Therefore, in this activity the subject does not have visual reasoning.

3.6. Step 6: Subjects plan to solve problems with determinations

The result of this activity is a plan to resolve the problem using determination. This decision was taken from previous experiences. This is evident from the following subject excerpts

“... It's the way (elimination and substitution) and after completion, the result of elimination is zero value, then it can be used another way that is determination... Way it's been common and
that's the way since high school even SMP has also been used... Attended junior high school teacher... The easiest way to use elimination and substitution”

Determination is the term used by the subject to resolve the problem. Determinations performed after the subject felt unsuccessful when attempting to resolve problems with elimination/substitution.

To achieve this decision, the subject of the subjects was inductive and deductive. The subject reasoned inductive because it considers that all problems identical to the given problem can be solved by elimination/substitution and determination. The subject reasoned deductively because the decision was taken from previous learning experiences. To get the decision, the subject does not involve a mental imagery. Therefore, the subject does not perform visual reasoning.

3.7. Step 7: Subjects implement plans to settle with determinations
The next step, the subject solves the problem using the matrix determinant. The subject's activity representation is as follows.

After writing the matrix, the subject stops and states that the settlement results indicate that the determination is zero.

The decision to resolve the problem with determinations is taken according to the previous plan. Therefore, for this activity, the subject reasoned deductive. For such reasoning, the subject does not involve a mental imagery as it only resumes the appropriate procedure plan. Thus, the subject is not visual reasoning.

3.8. Step 8: Subject checking results
After carrying out a plan to complaint problems with determination, the subject gets its value determination is 0. Re-examining activity is done by comparing the corresponding answer to the given issue. Because of its determination of 0, then the subject assesses that settlement with determination cannot solve the problem. Thus, the problem cannot be solved.

The result of this activity is a decision that determination could not solve the problem and need another effort to be able to solve the problem. The problem can be resolved if the determination is not 0. This decision is taken from the conformity inspection results between the completion and the expectation of resolving the problem. In this activity, the subject is deductive. For this reasoning, the subject has processed the information. However, in the processing of such information does not involve visual information (mental imagery). Thus, the subject does not perform visual reasoning.

3.9. Step 9: Subject plan resolves issues with coordinate points
Next step, the subject is planning to resolve the given issue using the coordinate point. The subject states the initiative is like the following quotation.

"... By means of the coordinate point it can be immediately found its completion"

The subject admits that the knowledge of the subject, the way that the subject get school time is the way of substitution, elimination, matrices and the latter there is a coordinate point.

The results of this activity are the decision to solve the problem by using coordinate points. This decision was taken as an alternative to solving problems. Alternative coordinate point as alternative problem solving is taken because elimination/substitution and determination cannot solve the problem. In addition, the subject find it easier to use for completion. In this activity, the subject is deductive. To obtain such a decision, the subject processes the information. The input information is a previous learning experience. Failure to try with determination and elimination/substitution to resolve the
problem encourages the subject to process the information again. The information is processed by selecting previous learning experiences and compared with its failure experience and compliance with the problems encountered. In the processing of such identification, the mind of the subject does not involve visual information (mental imagery). As such, the subject is not visually reasoning.

3.10. Step 10: Subject to implement plans to resolve issues with coordinate points

After planning to resolve the issue with the coordinate point, the subject carries out the plan. The subject's activity representation is as follows.

![Diagram of coordinate points](image)

The coordinate point is the term used by the subject. The subject mentions this activity with a coordinate point because it is imagined to find dots using a three-dimensional coordinate system. Thus, its completion is a sequential pair \((x, y, z)\).

The results of this activity are the decision to complaint issues as planned. This decision is taken based on the results of implementing a plan to settle by using coordinate points. Subject of reasoned deductive. The idea of solving a problem with a coordinate point is visual input. The subject raises a mental imagery with the visual input. Furthermore, the mental shading is processed quickly and perfected with calculations. The Output of this activity is the values of \(x, y, z\) as represented. To reason, the subject thinks. The subject performs information processing. This activity input information is a plan to resolve with the coordinate points and other available information. The subject uses the term completion method with the coordinate point, because the subject imagines the system of the coronary. The information processed involves visual information (mental shading). Thus, the subject is visual reasoning.

3.11. Step 11: The subject rechecks the results of its work with coordinates

After carrying out the plan, the subject rechecks the completion. Re-examining activity is done to get a decision on the correctness of the given solution. This activity is performed by a number of numbers obtained with equations 1.2 and 3. One representation of this activity is indicated by the following field notes.

The subject explains "... evidenced by substitution the equation... Equation one, equation two, equality of three and correct all, meaning this fits... After getting those answers, \(x, y\) and \(z\)... Related to the many transport cars... The results fit... ".

The results of this activity are the decision that the solution obtained is the right solution. This decision is derived from the results of re-examining the answers gained into the equations. Thus, the subject is reasoned deductive. In reason, the subject needs to think. The subject processes the information and examine by substituted into the equation. The subject does not describe it. Thus the subject does not involve a mental imagery. The subject is not visual reasoning.
4. Conclusion

To solve the problem of mathematics, female students perform the complex steps of completion of Polya, namely: Understanding problems with visualization, planning problem solving mathematically, planning solutions Problems with elimination/substitution, implement a plan to solve problems with elimination/substitution, examine the results, plan to solve problems with determinations, implement plans to resolve problems with determination, checking results, planning to solve problems with the coordinate points, implementing a plan to solve problems with the coordinate points, check the results of the sponsorship with the coordinate points. Each activity in resolving the problem, the subject has done reasoning. However, not all subject activities are identified to perform visual reasoning. Students tend to still focus on formalities. In the issue, the subject performs reasoning deductive or inductive and visualizes contextually and mathematically.

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