European Online Journal of Natural and Social Sciences 2022;
Vol.11, No 3 pp. 635-642
ISSN 1805-3602
www.european-science.com

Visual Thinking Skills in Solving Geometry Problems Based on Learning Style: Grounded Theory Study

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Received for publication: 17 March 2022.
Accepted for publication: 11 May 2022.

Abstract

This study seeks to determine students' visual thinking skills in solving geometric problems based on learning style inventory. The qualitative approach with the grounded theory research method was used. The research participants consisted of 61 students who were given a learning style inventory questionnaire, and 4 students were selected from each learning style category, namely converger, diverger, assimilator, and accommodator. Data collection techniques included learning style questionnaires and task-based interviews. The findings indicated that assimilator and converger students had good visual thinking skills in solving geometric problems and could explain logically every step they used while accommodator students had problems explaining logically at the planning and implementation stages of problem-solving. Meanwhile, diverger students could visualize the problem only at the stage of understanding the problem. At the next stages, they had difficulty in explaining logically, and the problem-solving process was not appropriate.

Keywords: visual thinking, problem-solving, learning style inventory, converger, diverger, assimilator, accommodator

Introduction

Good thinking skills are fundamental in solving mathematical problems and help in managing and utilizing the information received. According to Sword, there are three ways of thinking related to the brain processes based on the senses of hearing, sight, body senses, and feelings, namely auditory thinking, visual thinking, and kinesthetics thinking (Sword, 2005). This is shown in the following figure.

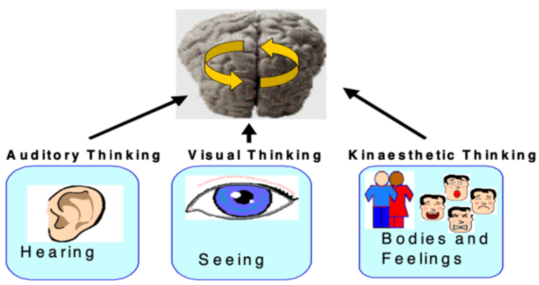

Figure 1. Three ways of thinking

One of the three thinking activities to help students learn mathematics is visual thinking. Arcavi defines visual thinking as the ability, process, and result of the creation of interpretation, use, and ideas about images, pictures, and diagrams on paper or using technological tools to describe and communicate information and ideas, develop previous ideas, and improve understanding (Arcavi, 2003). According to Brouseau, visual thinking is an intuitive intellectual process and visual imagination ideas, either in mental imaging or through images (Brouseau, 1991). Meanwhile, Bolton explains that visual thinking is a process of formulating and linking ideas and finding new patterns that emerge (Bolton, 2011). Anwar also suggests that visual thinking is the process and result of interpretation in understanding the information or concepts in the mind in the form of images, graphs, diagrams, or other forms that can help communicate information. Thus, visual thinking is a thinking ability that converts verbal statements into images, pictures, and graphics (Anwar, 2020).

Visual thinking plays an important role in successful learning because students who learn without using visual thinking skills are prone to misconceptions. Visual thinking skills play a role in solving problems from questions that require high-level reasoning. This is as per Presmeg statement that there are seven important roles of visual thinking in learning mathematics; they are to easily understand problems, simplify problems, see connections to related problems (involving previous related problems in the problem-solving experience), cater to individual learning styles, substitute computations/calculations, help examine solutions (visual representation can be used to check the correctness of the answers obtained), and convert the problem into the mathematical form (Presmeg, 2006).

Visual thinking skills have an important role in learning mathematics, including the success of learning geometry. Usiskin suggests that geometry is a branch of mathematics that studies visual patterns, connects the physical world or the real world, is a presentation of intangible or non-physical phenomena, exemplifies a system (Usiskin, 1982). Therefore, geometry learning aims to make students confident with their mathematical abilities, good problem solvers, able to communicate mathematically, and able to reason mathematically.

Preliminary studies explain that many students still have difficulty or failure in solving these problems, especially in the form of the plane and solid figures. When solving a problem, some students find it difficult to illustrate the problem in the form of mathematical pictures or models. This is as stated by Ma'rifah that student achievement in geometry is still below the average, which is 60%, and is at the lowest level; this is influenced by the abstraction of geometric objects (Ma'rifah, 2019). Therefore, the role of students' visual thinking in learning geometry is important. The geometry of the plane and solid figures is still a problem for students, so it is important to examine students' visual thinking skills in solving geometric problems.

In solving geometric problems, children will involve visual thinking, but their visual thinking processes are different from one to another. This difference is caused by their different experiences and understanding and processing of the information given. This difference is called *learning style*, which is an individual preference for the process or activity in learning. James & Gardner argue that learning styles are the most effective and efficient complex ways perceived by the students in processing, storing, and recalling what they have learned (Jame, 1995). This is also stated by Deporter & Hernacki that learning style is a combination of how someone absorbs, organizes, and manages information (Deporter, 1992).

Kolb classifies learning styles based on experiential learning or involving students' new experiences, developing observations/reflecting, creating concepts, and using theory to solve problems (Kolb, 1984). Humans can understand knowledge in two different ways, through concrete experiences and abstract concepts. Then, they can change the experience in two ways, through reflective observation or active experimentation. Thus, Kolb divides four types of learning styles, namely converger (abstract concept and active experiment), diverger (concrete experience and reflective observation), assimilator (abstract concept and reflective observation), and accommodator (concrete experience and active experiment) (Kolb, 2000).

Methodology

This study focused more on the process than on the results so that a qualitative approach was used because we want to obtain a positive picture of the characteristics of students' visual thinking skills in solving geometric problems. The research method used was the Grounded theory method, which is a procedure designed to build a theory that explains the concept of a process, action, or interaction about a substantive topic at a broad level (Creswell, 1998). The researchers used grounded theory to obtain a theoretical formulation as a strategy to identify students' visual thinking profiles in solving geometric problems in terms of learning style inventory.

Participants in this study consisted of 61 students who were given learning style inventory questionnaires. Then, they were divided into 4 groups of learning style categories, namely converger, diverger, assimilator, and accommodator. From each group, one student was interviewed to get in-depth information about students' visual thinking in solving geometric problems.

The instrument used in this research was a learning style inventory questionnaire adapted from Kolb's learning style inventory model which was used to determine subjects of the four categories. Furthermore, the geometry problem-solving test sheet was used to explore information about the visual thinking skills of students in solving geometric problems. The following are geometry problem-solving test questions given to junior high school students.

Problem: A lighthouse is 24 m high. The officer observes two ships from the top of the lighthouse. The observer's visibility with the first ship is 26 m and the second ship 40 m. The two ships and the foot of the lighthouse are in a line. Find the distance between the two ships being observed!

Then, data collection was carried out by task-based interviews. The interviews were conducted in a semi-structured format. This format was chosen to get natural and immersive data. The most important part of the interview is getting the stages of information sources in solving geometric problems. Data analysis was carried out by referring to the Corbin and Strauss procedure, which was simplified by Creswell into three, namely open coding, axial coding, and selective coding (Creswell, 2012).

Results and Discussion

Based on the analysis of the learning style inventory questionnaires of 61 students, the results showed the students have different learning styles. There were 4 assimilators, 6 converters, 45 diverges, and 6 accommodator students. After the students were given learning style questionnaires, they were given a geometry problem-solving essay test. The following is the description of students' visual thinking skills in solving geometric problems based on learning style inventory.

Visual thinking skills of assimilator students

The first activity in solving geometric problems is understanding the problem. The sources of information understand the problem by illustrating it in the form of pictures. The following illustrates the understanding of the problem in the question above.

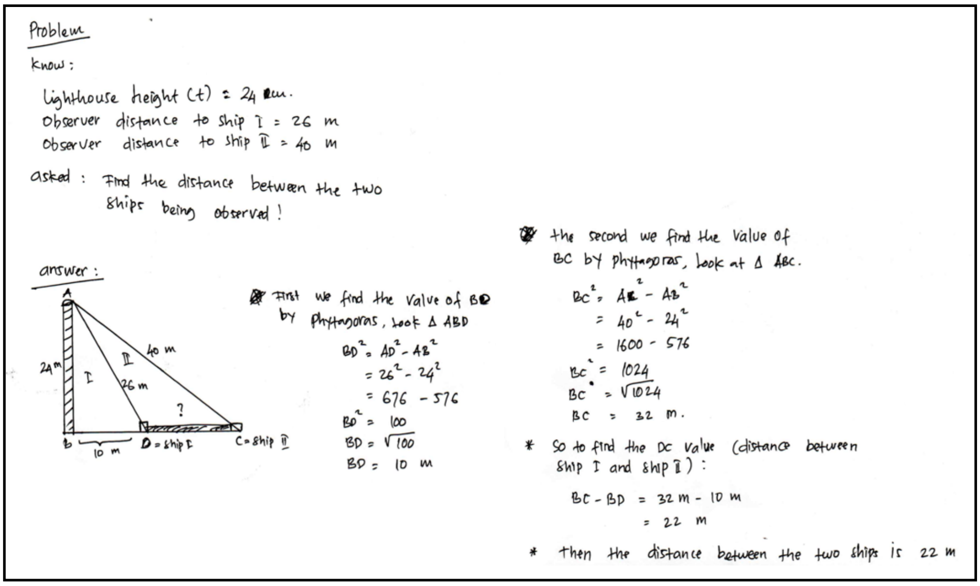

Figure 2. Assimilator subject illustration

Based on the figure above and the interview result, the assimilator student understood the problem by reading it twice, collecting and classifying information based on what was asked and known from the problem, looking for the relationship of the information obtained (what was asked, known, and needed to solve the problem but not mentioned in the problem) which is the key in solving the problem, expressing the problem by illustrating it in the form of a picture like Figure 2, and stating to determine the distance between the two ships (points D and C), which needs BD and BC.

The implementation of the problem-solving plan began by visually representing (pictures and) the plan, explaining it logically, expressing the pattern obtained and relating the pattern to find a solution. When solving problems, the student used the right pattern/strategy as stated in the development of the plan. Furthermore, the assimilator student stated that the solution obtained was correct, and there was no need for improvement or trying in other ways.

Thus, in solving geometric problems, the assimilator student could understand the problem well and visualize it in the right picture. He can solve the problem as planned and explain every step in solving the problem logically. This is following Kolb's opinion that assimilator students can understand problems and respond to various information presentations as well as organize or summarize them into a logical format (Kolb, 1984).

Visual thinking skills of accommodator students

The first activity in solving geometric problems is understanding the problem. The sources of information understand the problem by illustrating it in the form of pictures. The following illustrates the understanding of the problem in the question above.

Based on Figure 3 and the interview result, the accommodator student understood the problem by reading it twice to three times, collecting and classifying information based on what was asked and known only verbally without writing down the answer sheet, looking for the relationship of the information obtained (what was asked, known, and needed to solve the problem but not mentioned in the problem) which is the key in solving the problem, expressing the problem by illustrating it in the form of a simple image as shown in Figure 3.

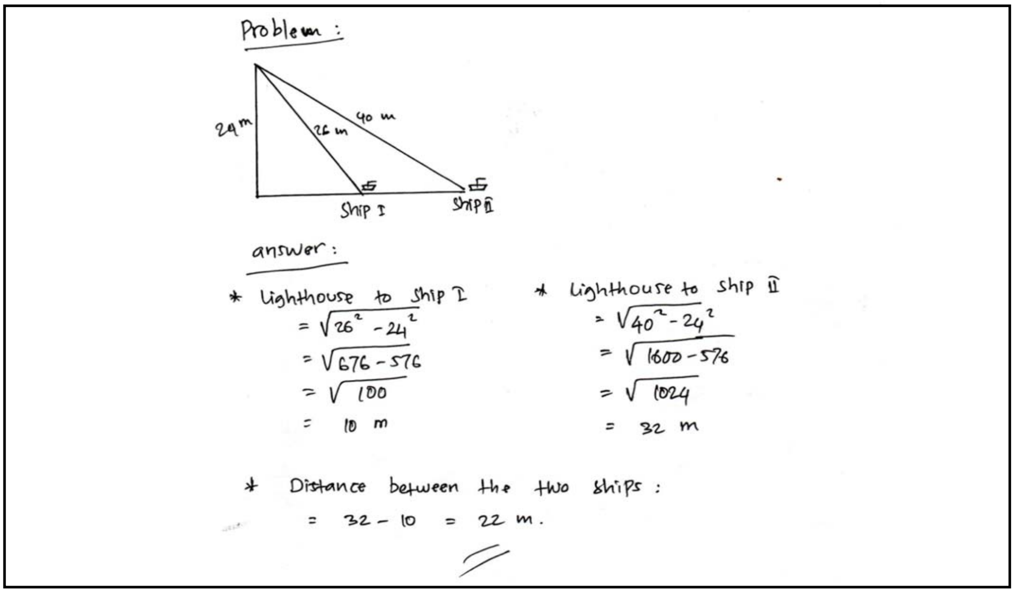

Figure 3. Accommodator subject illustration

In carrying out the problem-solving plan, he directly determined the distance from the lighthouse to ship I using the Pythagorean formula and the distance from the lighthouse to ship II, but he could not give reasons why using the Pythagorean formula. It shows that he cannot explain logically. He could express the patterns obtained and relate them to determine a solution when solving the problem using the right pattern/strategy as planned, but this solution was done by trial and error. Furthermore, he stated that the solution obtained was correct and there was no need for improvement or trying in other ways.

Thus, in solving geometric problems, the accommodator student could understand the problem well and visualize it into a simple picture. He could solve the problem as planned but could not explain every step in solving the problem logically. This is following Kolb's opinion that accommodator students usually solve the problems by considering the human factor (to get input/information) rather than technical analysis. They tend to act on intuition/impulse rather than logical analysis, often use trial and error in solving problems, lack patience, and want to act immediately. When there is a theory that is not following the facts, they tend to ignore it (Kolb, 1984).

Visual thinking skills of diverger students

The first activity in solving geometric problems is understanding the problem. The sources of information understand the problem by illustrating it in the form of pictures. The following illustrates the understanding of the problem in the question above.

Based on Figure 4 and the interview result, the diverger student understood the problem by reading it twice, collecting and classifying information based on what was asked and known from the problem, not looking for the relationship of the information obtained (what was asked, known, and needed to solve the problem but not mentioned in the problem) which is the key in solving the problem, expressing the problem by illustrating it in the form of a simple image as in Figure 4.

In planning problem solving, the diverger student could not express accurately; he only mentioned to determine the distance of ship I to ship II, so he had problems and applied the wrong procedure, even using the wrong formula, in carrying out the solution plan. He could not explain logically every step used in solving the problem. Because the problem-solving process used was not appropriate, the result was not correct, and he stated that he was doubtful that the answer was correct. In terms of written answers and explanations, in visualizing the problem, he only solved the problem by illustrating it in the form of pictures; meanwhile, at the planning and implementing stages, he had difficulties. This is as stated by Kolb that diverger students can imagine and act according to observations and feelings rather than a theory (Kolb, 1984).

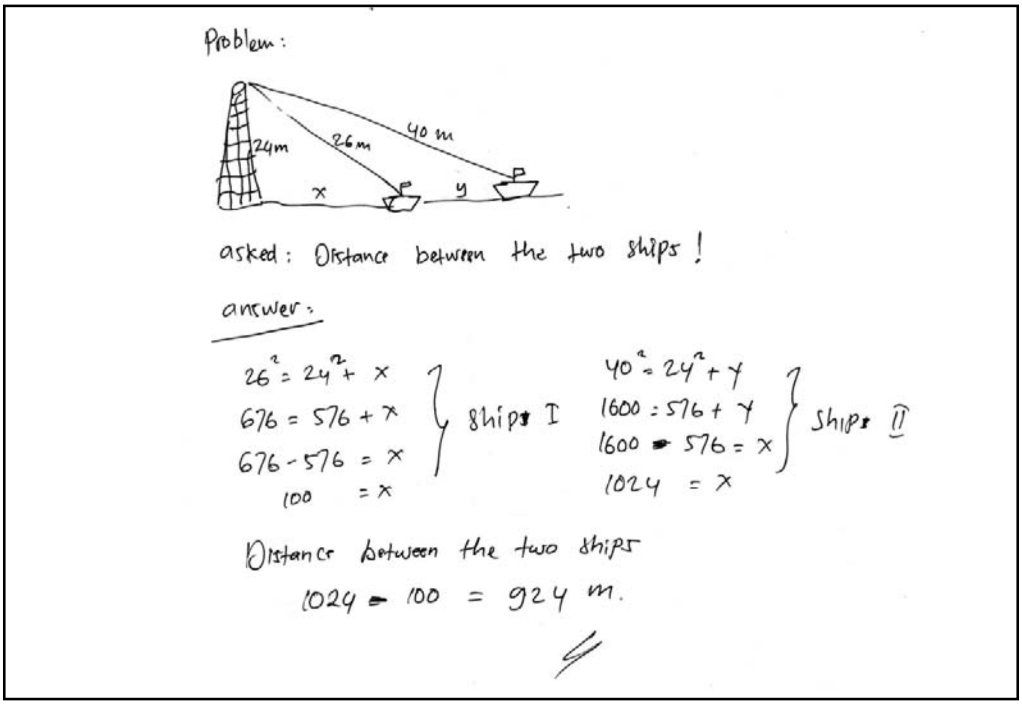

Figure 4. Diverger subject illustration

Visual thinking skills of converger students

The first activity in solving geometric problems for converger students is understanding the problem. The sources of information understand the problem by illustrating it in the form of pictures. The following illustrates the understanding of the problem in the question above.

Based on the figure above and the interview results, the converger student understood the problem by reading the problem twice, collecting and classifying information based on what was asked and known correctly, and looking for the relationship between the information mentioned in the problem with other information needed as a key in problem-solving. In planning the implementation of problem-solving, he mentioned that to find the distance between the two ships, the first thing to do was to find the distance between each ship and the lighthouse using the Pythagorean formula; then, the distance from ship II to the lighthouse was reduced by the distance from ship I to the lighthouse.

In carrying out the problem-solving plan, he referred to what had been revealed when planning problem solving and explained logically every step. He could also relate and explain each image in the ABD triangle to find the solution. He reviewed the answer by calculating again using the previous formula.

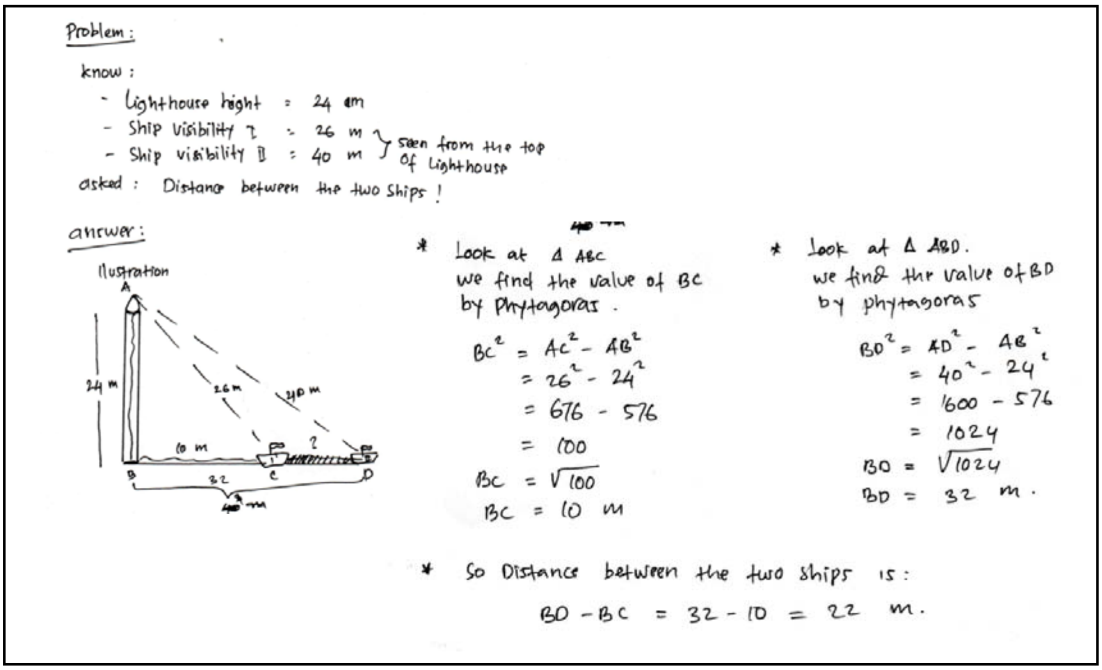

Figure 5. Converger subject illustration

Thus, in solving geometric problems, the diverger student could visualize the problem into a good image, complete it as planned, and explained every step logically. This is following Kolb's opinion that converger students have good ability in problem-solving and decision making and prefer technical (applicative) tasks (Kolb, 1984).

Conclusion

Based on the research objectives, the description, and analysis of the findings, the four subjects understand the problem by visualizing it in the form of pictures, but the accommodator and diverger students cannot explain their pictures logically. At the planning stage, only assimilator and converger students could explain the relationship of their pictures, so they could mention the right formula to solve the problem. Meanwhile, the accommodator and diverger students still had problems and difficulties in explaining the problem-solving plan. In implementing problem-solving, only the diverger student had problems because, from the planning stage, he had difficulty in mentioning the right formula used so that, in practice, he experienced obstacles, and even the process carried out each step was not right. However, the converger and assimilator students could explain each step logically, and the results were correct. At the reviewing stage, only assimilator and converger students did the re-calculation using the formula to make sure the results were correct.

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