Analysis of Trajectory Thinking of Middle School Students to Complete the Problem of Spatial Ability with Realistic Mathematical Education Learning

Fitri Mustika Arnis* Edi Syahputra Edy Surya
Department of Mathematics, Science Faculty, State University of Medan, Jl. William Iskandar Ps. V, Kenangan Baru, Sumatera Utara Indonesia

Abstract
This study aims to: 1) Know the results of the spatial ability test students taught with Realistic Mathematics Education Learning 2) find out the trajectory of thinking of junior high school students to solve spatial problems after Learning Realistic Mathematics Education. The population in this study were all students of Ali Imron Middle School Medan and the sample in this study were 31 student grade VIII SMP students. This research includes descriptive research using a qualitative approach. The research instrument was a test of spatial ability in solving geometry problems and interview guidelines. The subjects for the interview were chosen as many as 6 people based on their level of mathematical spatial ability. The results showed that: 1) The level of mathematical spatial ability in low-ability students has the highest proportion of as many as 12 students, followed by high-ability students 10 students and medium-ability students as many as 9 students. So, the percentage level of mathematical spatial ability of students with "low" abilities is 38.7%, ability is "medium" as much as 29%, and ability is "high" as much as 32.3%. 2) The stages of the creative thinking process possessed by students as the results and findings in this study are orientation, preparation, incubation, illumination and verification that will be skipped as students' point of thinking.
Keywords: *Spatial Ability, Realistic Mathematics Education Learning, trajectory of student thinking, creative thinking*
DOI: 10.7176/JEP/10-20-12
Publication date:July 31st 2019

Introduction

In its development, education in Indonesia faces several problems. The problems that arise from input, process, and output. Both the input, process, and output of the three are interrelated. Inputs influence sustainability in the learning process. The learning process also influences the output. And then the output will return to input (Megawati, 2015).

The results of evaluations of Middle school students in the United States as revealed by Clements & Battista (1992) illustrate that they failed to learn the basic concepts of geometry. The low mastery of geometry material does not only occur in students but also occurs in middle school math teachers. Learning geometry in schools should be directed at investigating and utilizing ideas and the relationships between the properties of geometry. In learning geometry students are expected to be able to visualize, describe and compare geometric shapes in various positions so that students can understand them.

Some areas of solving mathematical problems are related to spatial thinking. One of them is geometry. There are two standards used for learning geometry and both are related to spatial. In solving geometric problems everyone has their own way.

Spatial intelligence (spatial intelligence) is intelligence that includes thinking skills in images, as well as the ability to absorb, change and recreate various aspects of the visual-spatial world. Visual-spatial intelligence is concerned with the ability to accurately capture color, direction, and space. Children who have spatial abilities can recognize the object's identity when the object exists from a different perspective, and are able to estimate the distance and whereabouts of an object. Thus spatial ability is very important in the learning process and in recognizing the surrounding environment, for example, the ability of spatial relations which is a very important part of learning mathematics, especially geometry (Sari, 2018).

This spatial ability is not only an ability that must only be mastered by students in order to better understand the concept of building space, but their own spatial ability indirectly affects the mathematics learning outcomes (Indriyani, 2013). This is also confirmed by Hannafin, Truxaw, Vermillion & Liu (2010) students with high spatial ability showed significantly better performance than students with low spatial, if the spatial ability of mathematics possessed by students is high, then the students' ability to mathematics in general it is also high. Likewise stated by Shermann (Nasution, 2017) that he found a positive relationship between mathematics learning achievement and spatial ability.To be able to support the improvement of students' spatial abilities, the learning provided must support students to carry out real activities involving varied geometry objects and draw them. The involvement of these elements must be sought in learning that will be chosen or designed. Therefore the authors chose to use Realistic Mathematics Education (RME) learning or Realistic Mathematics Education. This is one way to take a stepwise approach starting from concrete, representational, to abstract. Kalbitzer and Loong (2013) provide ways to improve the spatial ability of students by using various kinds of representations, for example, lego, building drawings, and drawing activities using computer aids such as drag, resize, move, copy, paste, color, and delete. Realistic mathematic education approaches developed have met effective criteria and can improve mathematical spatial ability and students motivation (Putri, 2019).

Students perform a series of thought processes in solving geometric problems. In the thinking process, there are several paths or trajectories that are passed through by students, such as students must be able to visualize or illustrate geometric images in their dreams. Of course, this is closely related to the spatial intelligence possessed by each individual. A student with high spatial ability is more likely to be successful in the visualization process when compared to students with moderate or low spatial abilities. Such is the importance of this spatial ability so that teachers are required to give more than enough attention so that spatial abilities are truly taught in accordance with the curriculum mandate (Sari, 2018).

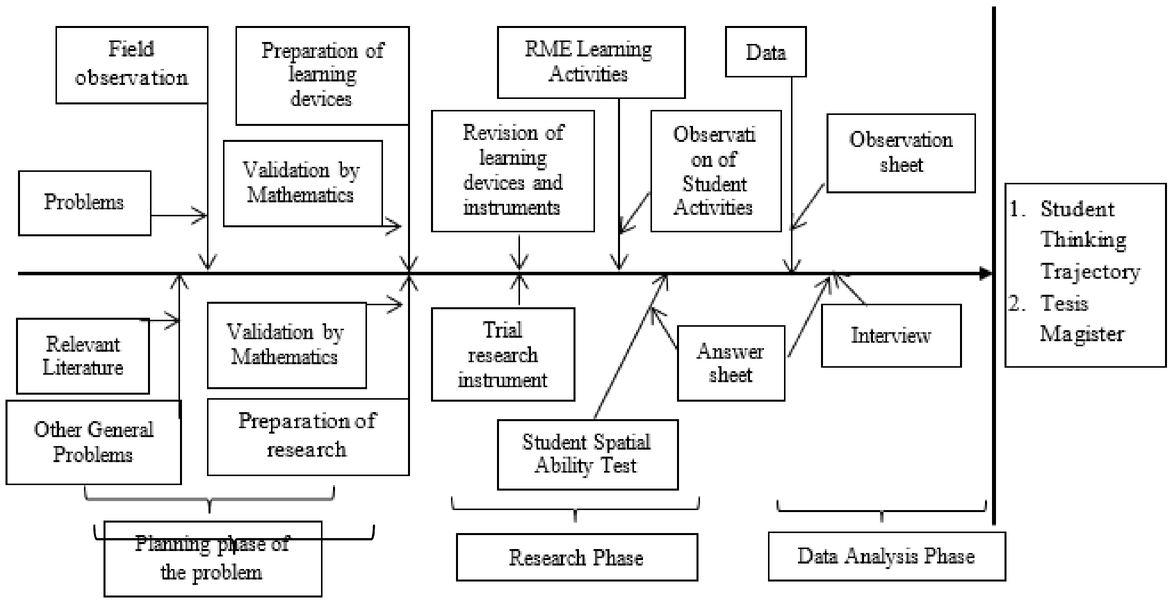
To find out more about the relationship between the level of spatial intelligence and the thinking trajectory (assimilation and accommodation) of students in solving geometric problems in the construction of pyramid spaces and prisms by using RME learning, the researcher intends to examine "the analysis of junior high school students' thinking in solving spatial problems after being taught through learning realistic mathematics education on pyramid and prism material ".

Methods

Research Pattern

This research includes descriptive research using a qualitative approach. Qualitative research is research that intends to understand the phenomenon of what is experienced by research subjects such as behavior, perceptions, actions, and others without making generalizations about what is obtained from research (Williams, 2007).

The data analysis technique in this study is data reduction, data presentation is then drawn conclusions. Look at the picture below



Picture 1. *Fishbone* Research Phase Diagram

From the Picture 1, the research process starts with field observations. At the time of field observation, the researcher approached (consulted) the principal, the mathematics teacher in the Ali Imron Medan Private Middle School. Then carry out observations on learning activities at the school. From the results of these observations, there will be problems, identification of problems and formulation of the problem.

The next step is to compile a Research Proposal. Preparation of research proposals includes the preparation of the design of the implementation of the research which includes the preparation of the introduction, literature review, research methods, learning tools and research instruments arranged with first consulted with the thesis supervisor. Then after the research proposal is accepted, validation and testing of the research instrument are carried out. Validation was carried out by the validator of the experts namely the Postgraduate Lecturer in Medan State University. Then the instrument was revised again.

Next is the implementation of mathematics learning using realistic mathematics education learning.

Learning is conducted during 4 meetings. During the learning process, student activities are observed. After completion of the study, the students carry out tests of mathematical spatial abilities. From the results of tests of mathematical spatial abilities, students will be selected by several students who will be interviewed. Interviews were conducted on selected subjects considering the subject can provide information in accordance with the research objectives. Then all the data obtained is collected all.

After all the data is collected, the next stage is data analysis. And from the results of data analysis, the results of the research and the findings of the research were obtained.

Participants

The subjects in this study involved class VIII students who were treated with learning Realistic Mathematics Education in the even semester of the 2018/2019 academic year with a total of 31 students. Then based on the results of the spatial ability test that is tested on students, several students will be selected as subjects to be subjected to interviews. Appointment of subjects subject to interviews is based on analysis (observations) of grouping the level of students 'thinking skills and based on students' spatial abilities.

Data Collection Technique

The process of collecting this data includes the process of entering the research location and being in a research location and collecting research data. According to Sugiyono (2008), there are four types of data collection techniques, namely observation, interview, documentation and combination/triangulation. The techniques used in this study were observation, interviews, documentation and joint / triangulation.

Tests of students 'spatial abilities were conducted to determine the increase in students' spatial abilities. This spatial ability test is arranged in multiple choices consisting of 20 items. Scoring in measuring spatial abilities using a fixed scale, each item has a weight of 5 on each item.

Interviews were carried out to selected subjects face-to-face between researchers and informants in a dialogical, question and answer, and discussion. The interview technique used is unstructured interviews. In accordance with the form of this interview, the researcher is not strictly bound to the interview guidelines. The implementation can be done anywhere and anytime as long as it relates to the phenomenon and focus of research. The type of interview used in this study is in-depth interviews.

Validity and Reliability

Validation of learning devices and instruments aims to obtain valid learning instruments and research instruments that are suitable for use in research. Learning devices and research instruments are validated by 5 experts. Based on the results of the learning device validation it was found that learning devices were good for use in learning. the validation of the research instruments was carried out statistical tests (empirically) to see the validity, reliability so that the validity of the research instruments was getting better.

Data Analysis

The data analysis used in this study is qualitative data analysis. The qualitative approach used in this study follows the concepts given by Miles and Huberman's (1994). Data obtained from the results of observations were analyzed to consider the implementation of further learning. The next stage is the stage of giving a test of students' mathematical spatial abilities. This test is carried out to obtain data on students' mathematical spatial abilities. This test is given to all subjects in the study, then an analysis of the test results (student answer sheet) is carried out.

After the analysis of the test of mathematical spatial abilities students continued at the interview stage. Interviews were conducted on the subject of research that had been determined. Interviews of the subjects were conducted based on the answer sheet of spatial ability to obtain data as a comparison (triangulation) of the description of the results of the answer sheet test of students' mathematical spatial abilities. Furthermore, based on the data, it will be explained later an analysis of the students' trajectory of thinking in solving spatial problems. Then the whole data that has been obtained is collected, both data obtained from interviews with students, answer sheets of spatial abilities of students, and data in the form of student recordings of learning are collected and re-analyzed for writing research reports.

Result and Discussion

Data on Spatial Ability Test Results

After carrying out learning using the RME Learning Model in building material for 4 (four) meetings, then continued the tests on students to see students' mathematical spatial abilities.

From the results of the corrected tests (Appendix E-1) presented the level of students' mathematical spatial abilities in Table 1.

Table 1. Level of Student Mathematical Spatial Ability

No	Score Interval	The number of students	Percentage	Category
1	$0 \leq \text{SK} < 65$	12	38,7%	Low
2	$65 \leq \text{SK} < 80$	9	29%	Medium
3	$80 \leq \text{SK} < 100$	10	32,3%	High

Subject Taking

For the interview phase, several students will be selected who will be interviewed based on the level of students' abilities and seen from the student activity data. The research subjects to be selected were adjusted to the spatial ability indicators of students grouped into three categories, namely (1) high; (2) medium; (3) low. The three categories of students were analyzed to obtain patterns of student answers. In each category 2 students will be selected. Students will be interviewed based on their answer sheets. So that it will be obtained how students think in answering spatial ability test questions which are triangulated based on the students' answer process working on LAS and videos during learning.

Based on the results of tests of students' mathematical spatial abilities that have been corrected according to the scoring guidelines, from 31 students selected as many as 6 subjects to be interviewed according to the level of mathematical spatial ability.

Analysis of Student Activity Data

Observation of student activities includes observing and recording the activities of students in selected groups from the beginning of learning to the final activities of learning. The division of groups in learning is heterogeneous in groups and spread both in individual abilities. Observation of active activities of students was carried out by three observers in each meeting on learning that applied the learning model of Realistic Mathematics Education. Student activities are activities carried out by students during the learning process, including: listening / paying attention to the explanation of the teacher / friend, reading / understanding problems, recording the teacher's explanation, discussing solving problems / finding ways and answering problems, communicating with the teacher / friends, arguing / expressing opinions , draw conclusions from information and do something that is not relevant to learning.

Table 2. Description of Student Activity Results

No	Observation Category	Average Time of Student Activity for Each Category (in percent)					Interval Tolerance
		I	II	III	IV	Average	
1.	Hear/pay attention to the teacher/friend's explanation	24,79	26,20	25,4	25,80	25,54	20%≤PWI≤30%
2.	Read/understand student books, questions on LAS and other sources	15	16,53	16,33	16,13	16	10%≤PWI≤20%
3.	Record teacher explanations, take notes from books/friends, solve questions, summarize group work	30,84	31,25	32,05	32,66	31,7	25%≤PWI≤35%
4.	Discuss/ask questions between students and friends, and between students and teachers	23	22,17	22,58	22,17	22,48	15%≤PWI≤25%
5.	Do something that is not relevant to learning.	6,45	3,83	3,63	3,22	4,28	0%≤PWI≤5%

Based on the information above, all categories of activities starting from category 1 to category 5 are already within the tolerance limit.

Discussion

The discussion was conducted in several stages, namely: interpreting research findings using relevant logic and theories; compare research findings with theories and other relevant empirical findings; and reviewing/reviewing new theories or modifying theories.

Stages of Student Creative Thinking Processes

The stages of the creative thinking process possessed by students as the results and findings in this study are orientation, preparation, incubation, illumination, and verification will be briefly described in this study divided into three abilities. The creative thinking process that students go through is in accordance with the stage of the creative thinking process that was presented by Munandar (2012), which includes four stages, namely the stages of preparation, incubation, illumination, and verification.

The stages of the creative thinking process in students who have a high level of spatial ability traverse several stages. The orientation as the initial stage of the creative thinking process that is traversed by high spatial ability students is in line with the opinion of Osborn (1950) who states that the initial stage a person goes through while carrying out creative thinking is the orientation stage, namely the problem recognition stage. Students first understand the problem in the problem before answering it. Then is the preparation stage, students gather the information they get from the problem. Learning realistic math education makes students able to put out more creative ideas. Students who have the high spatial ability are faster in knowing the information on the question. In line with Mulligan, Mitchelmore and Prescot (Scandpower, 2014) in their study found that students with a high level of awareness about patterns and structures tended to be smart in mathematical thinking and reasoning compared to their peers and vice versa. In addition, the time needed by students at the preparation stage is very diverse, depending on the level of ability of students and at the level of difficulty of the question, this is in line with the opinion of Feibleman (1945) which states that the variation in the time period can take several seconds or several hours or longer time. Students who have the medium spatial ability are rather fast in knowing the information on the question. But on questions that have a high level of difficulty, students who are of medium spatial ability also feel doubtful and confused in solving problems. And students who have the low spatial ability are long enough to know the information on the question. Students feel doubtful and confused in solving problems.

Furthermore, at the incubation stage, students who have high spatial ability do several activities, namely a short break, time to think about other things, ideas suddenly appear, have felt bored. This is in line with Segal (2004) which states that to solve mathematical problem solving after a while or for a long time the brain rests by diverting it to other problems. In students who have high spatial ability, the incubation stage occurs briefly. On relatively easy questions, students immediately generate ideas suddenly. The difference in the length of a person's incubation period is based on several factors. Such as the situation in working on the problem, the type of question given, and also the level of one's ability. Furthermore students who have spatial abilities are doing several activities, namely, a short break, had time to think about other things, ideas suddenly appear and had time to feel bored. In students with low spatial ability, the incubation stage occurs quite a long time. On relatively easy questions, it is difficult for students to get ideas. That makes students who have low spatial abilities only try to guess the answer if they really feel difficult.

At the illumination stage, students try to gather information and ideas they get to solve the problem. At this stage, students estimate the answers they will make and have found an answer. A person's experience from the preparation stage to the incubation period is accumulated into a collection of knowledge at the illumination stage which leads to the generation of new methods to solve problems, (Sriraman, Heavold, & Lee, 2013). Students with medium spatial ability have a pretty good ability to solve problems. And low-ability students have poor ability to solve problems

Finally in the verification phase, which is the final stage at the stage of the creative thinking process. Students who have a high level of spatial ability tend to feel confident about the answers they get. Students also do not ask answers to friends. In addition, students tend to re-examine the answers they have made. This means that students conduct a review of the answers they have produced. This stage is the second conscious stage after the illumination stage, where the process involves testing, verifying, evaluating, validating, writing creative ideas, monitoring, and publishing new ideas (Haylock, 1987).

Students who have a level of spatial ability are feeling confident about the answers they get. Overall, students who have spatial abilities are having good thinking processes in completing spatial ability tests. While students who have low spatial ability levels tend to feel unsure of the answers they get. Students also do not ask answers to friends. In addition, students also did not have time to examine the answers again. Students who have low spatial abilities also tend to ask their friends. This means that students who have low spatial abilities do not have good thinking skills.

Another theory that supports the results and findings of this study is Osborn's theory, but it is slightly different from Wallas's theory. Osborn's theory (1953), divides the stages of the creative thinking process into 7 (seven) stages, namely: orientation, preparation, analysis, ideation, incubation, synthesis, and evaluation. Osborn added the synthesis stage between the incubation and evaluation stages.

For students - students with high spatial abilities have a good process of creative thinking. According to the teacher, these students also belong to students who are smart in class. Whereas for students with low spatial ability, the process of creative thinking is not good. And these students also have low academic achievements. This is in line with the opinion of Leikin and Lev (2013) which states that students who excel in schools have a higher level of creativity than other students, although not necessarily the smartest students are the most creative students.

Student Mathematical Thinking Trajectory

The opinion of Mace and Ward (2002). Namely, students read and try to understand all problems; want to get mathematical ideas; trace what information is known and asked from the question, and look for pieces of information from contextual problems (eg size and formula to calculate the area of building space).

At the initial path of thinking, students try to understand the questions given. The length of time you understand each student is different. The factors that influence it are based on the level of spatial ability of students and also the level of difficulty of the questions. For students who have high spatial ability, they are usually able to understand the questions with a relative time faster for the easiest questions. For students who are of medium spatial ability can usually understand the problem with a rather fast time for the easiest questions. And finally for students who have a low level of spatial ability long enough for the easiest questions. Whereas to answer the most difficult questions, almost all students answer the questions for quite a long time.

On the second track is a plan to solve the problem. To solve problems, creative ideas are needed to answer questions. All available information is collected in order to find a solution. At this stage, the trajectory of the students varies. According to Osborn (1953), during the preparation stage, someone prepares to solve problems, find answers, ask other people to gather relevant data and information and find ways or approaches to find solutions. In high-ability students to find solutions does not require a long time and creative ideas appear suddenly. In students who are medium-ability of requiring quite a long time to need a solution, but not as long as such a low ability. The next track that is passed by students with medium spatial ability is that students have a break, reflect on answers, think about other things, and also get bored. Then for students with the low spatial ability on this track, it takes a long time. Almost all students pass a fairly long incubation period. Like, had felt bored, had a short break, pondered answers, thought of other things, and also ignorance of problems. Students with low spatial ability are very long to pass this path. Students find difficulty in finding answers.

After the idea appears, the path that is passed is resolved the problem. At this stage, for questions that are relatively easy, students can immediately find the answer. Students also feel confident about the answers they get. In addition, overall, high-spatial ability students did not have time to ask answers to their friends. The student only tries to re-examine the answer. For students who are of medium spatial ability, after knowing how to solve the problem, students immediately find the answer. The time needed to answer questions is rather long. However, students who are capable in general feel confident about the answers they make. Although there are some questions that he feels doubtful and asks answers to his friends. Then he also had time to improve his answer. On this trajectory, students who have low spatial abilities need a long time to find the answer. In addition, students also do not know how the solution to the problem. So that at this stage, students who have the overall low spatial ability only come from guessing answers. The last track that was passed was the final decision after finding the answer. In students who have the low spatial ability, they often ask answers to friends. Students feel uncertain about the answer.

Conclusion

1) Of the 31 students, the level of mathematical spatial ability in low-ability students has the highest proportion of as many as 12 students, followed by high-ability students 10 students and medium-ability students as many as 9 students. So, the percentage level of mathematical spatial ability of students with "low" abilities is 38.7%, the ability is "medium" as much as 29%, and ability is "high" as much as 32.3%.

2) At the initial path of thinking, students try to understand the questions given. The length of time you understand each student is different. For students who have high spatial ability, they are usually able to understand the questions with a relative time faster for the easiest questions. On the second track is a plan to solve the problem. To solve problems, creative ideas are needed to answer questions. All available information is collected in order to find a solution. After knowing how to solve the problem, the trajectory than the students immediately finds the answer. The time needed to answer questions varies for each ability. High spatial ability is the time needed to answer questions for a while and feel confident about the answer. while for students with low spatial ability, students need a long time to find the answer. Students feel uncertain about the answer.

REFERENCES

Clements, D.H., & Battista, M.T. 1992. Geometry and spatial reasoning. In Grouws D.A. (Ed.), *Handbook of research on Muthematics Teaching and Learning*, (pp. 420- 463), New York: Macmillan.

Feibleman, J.K., 1945. The Psychology of the Artist. *Psych*, 19, pp.165-89.

Hannafin, Robert D., Truxaw, Mary P., Vermillion, Jennifer R., Liu, Yingjie. (2010). Effects of Spatial Ability and Instructional Program on Geometry Achievement. *The Journal of Educational Research Volume 101, Issue 3*. pp. 148-153. https://doi.org/10.3200/JOER.101.3.148-157

Haylock, D.W., 1987. A Framework for Assessing Mathematical Creativity in Schoolchildren. *Educational Studies in Mathematics*, 18, pp.59-74

Indriyani, E. 2013. *Perbedaan Peningkatan Kemampuan Spasial dan Disposisi Matematis Siswa yang Diberi*

Pembelajaran Geometri Berbasi Teori Van Hiele dengan dan Tanpa Aplikasi Wingeom di SMP Negeri 4 Binjai. Unpublished thesis. Medan:. Unimed Graduate School in Medan.

Kalbitzer, S & Loong, E. 2013. Teaching 3-D Geometry- the Multi-Representational Way. Australian *Primary Mathematics Classroom*, 3, 23 – 29. https://files.eric.ed.gov/fulltext/EJ1093211.pdf

Leikin, R. & Lev, M. (2013). Mathematical creativity in generally gifted and mathematically excelling adolescents: What makes the difference? ZDM - *The International Journal on Mathematics Education*, 45(2), 183–197.

Mace, M.& Ward, T., 2002. Modeling the Creative Process: A Modeling the Creative Process: A Grounded Theory Analysis of Creativity in the Domain of Art Making. *Creativity Research Journal,* 14, pp.179-192. https://doi.org/10.1207/S15326934CRJ1402_5

Megawati, P, 2015. Meretas Permasalahan Pendidikan di Indonesia, Jurnal Formatif, dalam journal.Ippmunindra, hal. 228

Miles, M. B., & Huberman, A. M. (1994). *Qualitative Data Analysis* (2nd ed.). Thousand Oaks, CA: Sage Publications.

Munandar, U. (2012). *Pengembangan Kreativitas Anak Berbakat*. Jakarta: Rineka Cipta.

Nasution, E. Y. P. 2017. Meningkatkan Kemampuan Spasial Siswa Melalui Pembelajaran Geometri Berbantuan Cabri 3D. *MATHLINE.* Vol, 2. No, 2. 194-179

Osborn, A., 1953. *Applied Imagination*, New York: Charles Scribner.

Putri, S, K,. Hasratuddin,. Syahputra, E.(2019). Development of Learning Devices Based on Realistic Mathematics Education to Improve Students' Spatial Ability and Motivation. INTERNATIONAL ELECTRONIC JOURNAL OF MATHEMATICS EDUCATION. Vol. 14, No. 2, 393-400. https://doi.org/10.29333/iejme/5729

Sari, D. P., Syahputra, E., & Surya, E. (2018). An Analysis of Spatial Ability and Self-efficacy of Student in Cooperative Learning by Using Jigsaw at Smas Muhammadiyah 8 Kisaran. *American Journal of Education Research*, *6*(8), 1238-1244. https://doi.org/10.12691/education-6-8-25

Scandpower, Fenna van Nes & Michiel Doorman. (2014). Fostering Young Children's Spatial Structuring Ability. *International Electronic Journal of Mathematics Education* –IΣJMΣvol 6 pp 27-30

Segal, E., 2004. Incubation in Insight Problem Solving. *Crestivity Research Journal*, 16(1), pp.141-14. http://doi.org/10.1207/s15326934crj1601_13

Sriraman, B., Haavold, P. & Lee, K., 2013. Mathematical Creativity and Giftedness: A Commentary on and Review of Theory, New Operational Views, and Ways Forward. *ZDM Mathematics Education*, 45(2), pp.215-225. http://doi.org/10.1007/s11858-013-0494-6

Sugiyono, 2008. *Metode Penelitian kuantitatif, Kualitatif, dan R & D*. Bandung: ALFABETA.

Williams, Carrie. (2007). Research Methods. *Journal of Business & Economic Research*. Volume 5, Number 3