Analysis of Geometric Thinking Students' and Process-Guided Inquiry Learning Model

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Abstract. This research aims to analysis students' geometric thinking ability and theoretically examine the process-oriented guided inquiry (POGIL) model. This study uses qualitative approach with descriptive method because this research was done without any treatment on subjects. Data were collected naturally. This study was conducted in one of the State Junior High School in Bandung. The population was second grade students and the sample was 32 students. Data of students' geometric thinking ability were collected through geometric thinking test. These questions are made based on the characteristics of geometry thinking based on van hiele's theory. Based on the results of the analysis and discussion, students' geometric thinking ability is still low so it needs to be improved. Therefore, an effort is needed to overcome the problems related to students' geometric thinking ability. One of the efforts that can be done by doing the learning that can facilitate the students to construct their own geometry concept, especially quadrilateral’s concepts so that students' geometric thinking ability can enhance maximally. Based on study of the theory, one of the learning models that can enhance the students' geometric thinking ability is POGIL model.

1. Introduction
Geometric thinking is one of the mathematical ability in geometric learning. One of topic in early grade in junior high school which involves the geometric thinking ability is quadrilateral. Quadrilateral is an appropriate subject to describe students' geometric thinking ability [3]. Based on previous studies, difficulties are still found in learning of geometry.

There are misconceptions and lack of knowledge related to geometry in seventh-grade students [4]. One of the causes of the misconception is because students only memorize the formula of a plane without understanding the concept. there were errors and misconceptions in eighth-grade students [5]. Students only pay attention to the physical appearance of geometry image without understanding their properties. These problems also happened in Indonesia. Some research showed that there are misconception in geometry and students' geometric understanding are still low [6, 7, 8].

One of the reasons these problem is the learning in the classroom is only as a process of transferring knowledge from teacher to student so students only memorize without understanding the concept given. Learning of geometry in secondary schools assumes that students have been thinking at the level of formal deduction. However, in reality, this is not the case and students' understanding of geometry is lacking [3]. In the other research, one of the problems in teaching and learning geometry is that students have lack basic foundation in mathematics, students can not solve the problem even when the examples are given [9]. Therefore, a learning model is needed which can provide an
opportunity for students to construct their own geometry concepts, especially the concept of quadrilateral so that students not only memorize but also understand the concept.

In learning of geometry we must to pay attention on student level thinking and learning process [3]. Therefore, in this article, the author wants to analysis students' geometric thinking ability and to examine the process oriented guided inquiry learning model.

2. Experimental Method
This study uses qualitative approach with descriptive method because this research was made without any treatment on the sample and examine factual problems which related to the Process-Oriented Guided Inquiry Learning Model. Research data was collected naturally. This study was conducted in one of the State Junior High School in Bandung. The population was eighth grade students and the sample was 32 students. Data of students' geometric thinking ability were collected through geometric thinking test. These questions are made based on the characteristics of geometry thinking on van hiele's theory. Procedures in this research are identifying the problem, reviewing the literature, arranging the instrument test, collecting the data, analyzing the data and making the conclusion.

3. Result and Discussion
Geometric thinking is one of the ability which was used in studying and applying geometric concepts. The concept of geometry is not only used in math lessons but also used in various fields in real life, such as in the field of architecture, art, urban planning, etc. The importance of the geometric concept as described in the introduction requires students to develop their geometric thinking ability well. Geometry has a greater opportunity for students to understand than any other mathematical material. Because there are many instances in real life which associate with geometry. Descriptions of students' geometric thinking ability based on the results can be described as follows.

3.1. Analysis of first indicator: presenting the problems of geometry in image form and solve them
Overall the students can answer correctly. Students can draw nine pieces of square that arranged into a large square in accordance with the instructions question. Question in this indicator is “Draw nine squares, the size is 2 cm x 2 cm, become large square”. Based on students answer, they can draw a square. However, there are some students who can not draw the square appropriate with the instructions. There are some students who don’t familiar with the properties of the square so students compose the nine squares horizontally so that it will not form a new larger square.

When answering the next question, which is “how many square are visible on the drawing you have created?”. There are four types of answers given by the students. The student answer types are 1 square, 9 square, 10 square and 14 square. The reason the students can thus be seen in Figure 1 above. This indicates that the students recognize the properties of the square building but have not been able to apply these properties when analyzing more complex images. This is evident from the interviews that show the students know that the square has four sides of the same length, but can not apply them in analyzing the images they have created. Based on the results of interviews conducted, there are still some students who have not understood the meaning of some of the terms of the geometry. For example, there are students who say that the four angles of the square are the same length. While we know that the element of a square that has length in the square is its side, not the angle. The photograpf of students’ answers can be seen in the figure 1.
3.2 Analysis of second indicator: using the plane’s properties in solving mathematical problems

Question in this indicator is “PQRS is a rhombus with PQ = (5x – 3) cm and QR = (2x + 3) cm. find the circumference of that rhombus then explain your answer”. Based on the students’ answer, there are 12 students who answered correctly. There are 12 students who can not solve the problem completely. There are 8 students who can answer the question, but not complete. This indicates that the students knew the properties of the rhombus that length of the four sides are same. Students can search for the value of x by utilizing the properties of the rhombus. Based on the interview, overall students have known the characteristics of the rhombus. Most students have difficulty when determine the value of x because they have not mastered the concept of algebra. This can be seen from the student’s answer that does not show the steps to get the value of x, but the students directly guess the value of x which is then directly substituted into the equations of the sides so as to obtain the length of each side. Some photograph of student answers can be seen in the figure 2.

3.3 Analysis of third indicator: using the concept of Plane in solving contextual issues

Question in this indicator is “a garden look a like rectangle with have measure 9 m x 6 m. There is a street which surrounds that garden. Width of the street is 1.5 m. Find area of that street”. Overall students have difficulty in solving the problem No. 3, even many students who can not construct the image from the problems given. Only five students who can answer correctly. Based on the student’s
answer, they do not understand the concept of the circumference and the area of the rectangle when given the problems involving the two plane. This indicates that students are not familiar with the problems that require any analysis of the given problem. Some photograph of student answers can be seen in the figure 3.

![Figure 3. The Photograph of Students’ Answer on Problem No. 3](image)

### 3.4 Analysis of fourth indicator: connecting the two geometry by its properties

Question in this indicator is “Whether a rectangle can be regarded as parallelogram? In the other, whether a parallelogram can be regarded as rectangle?”. Based on the answers given by the students, there are 8 students who answered correctly. However, students can not express the reasons as expected. Based on students' answers, it appears that students know the properties of rectangular and parallelogram. However, students can not relate the relationship between rectangular's properties and parallelogram's properties. Students only understand the properties of the two planes separately. Consequently, the students can not classify the two planes based on the interrelatedness of their properties. This shows that students only recognize these properties of plane without being able to relate the relationship between these properties. Some photograph of student answers can be seen in the figure 4.

![Figure 4. The Photograph of Students’ Answer on Problem No. 4](image)

### 3.5 Analysis of last indicator: giving a logical reason to the problems given

Question in this indicator is “ABCD is a rhombus with angle ADB measure 45° then find mesure of angle A, B, C and D”. There are only three students who can answer no. 5 correctly. Based on figure 5, it appears that the students have not understood the properties of the rhombus. Students only see images without understanding the information contained in the given problem. Photograph of student answers can be seen at the figure 5.
Based on the above description, it can be seen that students' geometric thinking ability really need to be improved. The good students' geometric thinking especially in the plane material will greatly assist students in faced the other subjects, especially in other geometry materials such as “bangun ruang sis datar”. Therefore, teachers should be able to overcome these problems. One way to overcome the problems that have been described is to prepare a learning that can help students construct their own geometry concept, especially on the subject of a rectangular. Teachers should plan lessons according to Van Hiele's theory [10]. According to van hiele's theory, in learning geometry should pay attention to the students' geometric thinking level. In addition, van hiele also revealed that in geometry learning preferably through five phase van hiele. The five phases are inquiry, direct orientation, explication, orientation and integration [11].

In the inquiry phase, teachers should be able to invite students to focus on what they will learn. For example, teachers can give some questions to students about plane, ask the students to discuss subjects that will be learned by utilizing their existing knowledge. In the phase of direct orientation, students explore topics that will be learned through what teachers have prepared. Teachers should be able to create activities that can lead students to construct the concepts that will be learned. In the explication phase, students discuss the relation between the observed object and its properties based on their existing knowledge. In this phase, the teacher can help students to a minimum of the appropriate language. In the orientation phase, students are faced with a more complex problem, which requires many stages to complete. Through these problems, students will develop their experiences so as to find ways to solve them. Students will discover the interrelationships between geometric concepts (especially on the plane), something that was originally implicit in being explicit to students. In the integration phase, students review and summarize what has been learned in order to establish a new picture of the interrelationships between objects. In this phase, the teacher can assist the student by completing what the student has learned.

One of the learning models that match with the five phases of van hiele is a process oriented guided inquiry learning (POGIL) model. POGIL is a learning model based on observation, on what students learn well [12]. POGIL helps students recognize the two components of education, content and process [13]. Furthermore, Hanson points out that in classes using POGIL, students will work in group that can support students to master the content learned and develop the ability of learning, thinking, problem-solving, communicating, teamwork, management and assessment. The most important thing in POGIL is to familiarize the students with the ability to think rather than memorize. Teamwork in POGIL aimed to develop students' skills by helping each other among team members.

POGIL has a learning cycle, namely exploration, concept discovery and application of concepts [14]. In the exploration phase, students look for information or patterns. Teachers should be able to facilitate students in exploring activities for example by providing various models of objects to be learned so as to create activities that guide students in finding the concepts to be learned. In addition, teachers can provide questions that make students think critically so they can find concepts to be learned. Furthermore, in the phase of concept invention, students discuss the information they obtained from the previous stage so that students find the connection between the object they observe and their properties. The last phase is the application. This stage assists students in combining students' understanding with appropriate explanations and familiarizing students with appropriate
terms. Teachers can help students by giving conclusions of what students have discussed and practice questions. Illustrate of the cycle can be seen in the figure 6.

![Figure 6. POGIL’s Cycle](image)

Based on the above explanation, it appears that the POGIL model match with the five phases of van hiele, so it can be applied in the learning of geometry. The relationship between the five phases of van hiele with the cycle in POGIL can be seen in the table 1.

| Van Hiele Phase | POGIL’s Cycle |
|-----------------|---------------|
| Inquiry         | Exploration   |
| Direct Orientation | Concept Invention |
| Explication     | Application   |
| Orientation     | Integration   |
| Integration     |               |

Research on POGIL model has been done in many subjects. POGIL model is effective in increasing students’ higher order thinking skill and process skill [15]. The other research found that POGIL model effective to enhance students’ academic performance [16]. Furthermore, POGIL model can be used to develop students’ competencies in mathematics [17].

4. Conclusion
Based on the results and discussion, student’s still have difficulties in geometric thinking. Therefore, an effort is needed to overcome the problems which related to students' geometric thinking ability. One of the efforts that can be done is by doing the learning that can facilitate the students to be able to construct their own geometry concept, especially quadrilateral’s concept so that students' geometric thinking ability can develop maximally. Based on study of the theory, one of the learning models that can enhance the students' geometry thinking ability is POGIL model.

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References
[1] Kennedy L 1994 *Guiding Children’s learning of Mathematics* (California: Wadsworth Publishing Company)
[2] Clements and Batista 1992 *Geometry and Spatial Reasoning Dalam D. A. Grows,* (Eds). Handbook of Research on teaching and Learning Mathematics (New York: MacMilan Publisher Company) pp. 420-464
[3] Van Hiele P M 1999 *Developing Geometric Thinking trought Activities that Begin with Play.* Teaching Children Mathematics (Reston VA: NCTM) pp. 310-316
[4] Ozerem A 2012 Misconceptions in Geometry and Suggested Solution for Seventh Grade Students. *International J. of Trends in Art, Sport and Science Education* 1(4)
[5] Biber C, Tuna A and Korkmaz S 2013 The Mistakes and The Misconceptions of The Eighth Grade Students on The Subject of Angels *European J. of Science and Mathematics Education* 1(2)
[6] Nursyam S Z 2012 Analisis Kemampuan Pemahaman Geometri Siswa SMP Kota Ternate berdasarkan Tahapan Van Hiele *J. Matematika dan Pendidikan Matematika* 1(1)
[7] Roskawati, Ikhsan M and Juandi D 2015 Analisis Penguasaan Siswa SMA pada Materi Geometri *Didaktik Matematika* 2(1)
[8] Kurniawati M, Junaedi I and Mariani S 2015 Analisis Karakteristik Berpikir Geometri dan Kemandirian Belajar dalam Pembelajaran Fase Van Hiele Berbantuan Geometers Sketchpad *J. of Mathematics Education Research Unnes* 4(2)
[9] Adolphus T 2011 Problems of teaching and learning of geometry in secondary school in Rivers State, Nigeria *International J. of emerging Science* 1(2)
[10] Yadzani M 2007 Correlation between students’ level of understanding geometry according to the van hiele’s model and students’ achievement in plane geometry *J. of mathematical sciences & mathematics education*, 1(5)
[11] Crowley M L 1987 *The Van Hiele Model of The Development of Geometric Thought.* Dalam Linquist, M. M and Shulte, A. P. (Eds), Learning and Teaching Geometry, K-12 (Reston VA: NCTM) pp 1-16
[12] Straumanis A 2010 *Classroom Implementation of Process Oriented Guided Inquiry Learning: A Practical Guide for Instructors POGIL.* Organic Chemistry A Guided Inquiry, Second Edition
[13] Hanson, D M 2006 *Instructor’s Guide to Process-Oriented Guided Inquiry Learning* (New York: Pasific Crest)
[14] Moog R S, Creegan F J, Hanson D M, Spencer J N and Straumanis A R 2006 Process-Oriented Guided Inquiry Learning: POGIL and The POGIL Project *The J. of Metropolitan Universities* 17
[15] Barthlow (2011) *The effectiveness of process oriented guided inquiry learning to reduce alternate conceptions in secondary chemistry* (Disertation) Liberty University.
[16] Villagonzalo E C (2014) *Process oriented guided inquiry learning: an effective approach in enhancing students’ academic performance the DSLU research congres Filipina*
[17] Purnomo M E R and Abadi A M (2015) The implementation of POGIL in mathematics learning process to develop students’ competencies within curriculum 2013 *Proceeding of international conference on research, implementation and education of mathematics and science* 2015, Yogyakarta University