Development of Geogebra-assisted student worksheet for transformational geometry learning

H P Lestari, Sugiyono and E Listyani
Department of Mathematics Education, Universitas Negeri Yogyakarta, Indonesia

E-mail: himmawati@uny.ac.id, endang_listyani@uny.ac.id

Abstract. This study aims to develop Student Worksheets assisted by Geogebra software to be used in Geometry Transformation lectures. This research is a development research to develop Geogebra assisted Student Worksheet for Transformational Geometry learning. This development research refers to the Jan van den Akker model, namely: 1) Preliminary investigation, 2) Theoretical embedding, 3) Empirical testing, and 4) Process and results of documentation, analysis and reflection. The instruments in this study are the Observation Sheet and Tests. The results of this study are a set of Student Worksheets that can be used in Transformational Geometry learning. The Student Worksheets contain several student activities using Geogebra software to improve student problem solving skills. In general, developed Student Worksheets are of good quality. The aspect of practicality of Student Worksheets meets very good criteria based on student responses, namely with a score of 3.33 from the maximum score 4. Judging from the aspect of effectiveness, Student Worksheets meet good criteria based on the results of student problem solving ability tests, which score is 2.34 from the score maximum 4. The constraints faced in developing and implementing Geogebra-assisted worksheet are that students are still not fluent using Geogebra software and are still having difficulty interpreting Geogebra's appearance and output.

1. Introduction
The learning process requires media and teaching materials, besides an adequate environment. The role of the lecturer emphasized more in designing various sources, and facilities students in learning something. Students are the center of the teaching and learning process, and then learning needs to empower all potential learners to master the expected competencies.

Geometry is an axiomatic system because it consists of undefined elements, elements that are defined, postulates (axioms), and theories or propositions made based on elements that are not defined and elements that are defined. It is known that Pierre van Hiele and Dian van Hiele-Geldof stated that in studying Geometry students experience the development of thinking skills through the following levels: 1) Recognition or visualization, 2) Analysis, 3) Ordering or informal deductive, 4) Deduction or formal deductive, 5) Applied skills.

The Transformational Geometry course discusses geometry based on transformation groups that include isometry (identity, translation, reflection, rotation, glide reflection) and similarity (dilation, dilative reflection, and dilative rotation) using synthetic, analytic / algebraic, and matrix approaches.
In addition to visualizing abstract geometrical concepts, students must also be able to think axiomatically and analytically in solving the problem of Transformational Geometry. In lectures on Transformational Geometry, visualization of changes in location and shape changes plays an important role for the inculcation of concepts and stimulates exploration of the properties of various types of transformation. However, drawing geometry only requires a long time, especially while drawing accurately, accurately, and quickly shading an object after subjected to transformation. Therefore, the right learning media is needed to carry out Transformational Geometry learning.

The National Council of Teachers of Mathematics (NCTM), defines the media in the sphere of education as anything that can be manipulated, seen, heard, read, or talked about along with the instruments used for these activities. NCTM states that technology is one of the basic principles in "high-quality mathematics education" [1].

Geogebra is dynamic mathematical software that combines geometry, algebra and calculus. Geogebra has two elements, namely Dynamics Geometry Software (DGS) and Computer Algebra Systems (CAS) [2]. Geogebra is free software that can be used to construct geometry objects manually or through algebraic input, display visualizations of an algebraic equation, and manipulate objects including transforming geometric objects.

Thus, the use of Geogebra software is very necessary in learning Transformational Geometry. What's more, the Transformational Geometry course discusses changes in the position and shape of geometric objects which really require accurate and fast visualization.

Based on the results of the Lesson Study "Utilization of ICT in Learning Transformational Geometry to Increase Student Activity" that was carried out by the previous team [3], it is obtained some results. One of them is computer-based learning media, lecturers can optimize the use of time and students can get visualizations about concepts in Transformation Geometry, such as changes in position and shape changes due to transformation using computer-based learning media. That students’ activity is written on student worksheets. Unfortunately, students also still find difficulties in solving problems in geometry. Whereas, problem solving is an important skill for students. Problem solving skill give students training to solve the problems in real life. Problem-solving is a vital part of mathematics learning, so its existence can't be separated from mathematics program [7]. Pimta, Tayruakham, and Nuangchalerm [8] stated that problem-solving is considered as the heart of mathematics learning because the skill is not only for learning the subject but it emphasizes on developing thinking skill method as well.

So, it is important to develop student worksheet which was equipped with Geogebra files to support student activities oriented to solving problems. The objectives of this study are to: 1) Describe Geogebra-aided worksheet for Transformational Geometry learning, 2) Describe the effectiveness of Geogebra-assisted worksheet, and 3) Describe the obstacles faced in developing and implementing Geogebra-assisted worksheet in the Transformational Geometry learning.

2. Research Methods

2.1. Types of Research

Type of the research is a Research and Development which is intended to develop Student Worksheet assisted by Geogebra software for Geometry Transformation learning. This research consists of 3 stages, namely the preparation phase, the development phase, and the final stage. The development phase consists of four steps, that is preliminary investigation, theoretical embedding, empirical testing, and analysis and reflection.

2.2. Time and Place of Research

This research was conducted in May-November 2017 at Mathematics and Natural Sciences faculty of Yogyakarta State University.
2.3. Research Subjects
The product trial subjects of worksheet users were students in Mathematics Education Study Program who join Transformational Geometry course 2017/2018.

2.4. Instruments and Data Analysis Technique
The instruments are 1) Student questionnaire, used to obtain data about student responses, 2) Observation sheet, used to see the implementation of learning using the worksheet, 3) Achievement test, used to measure the effectiveness of worksheet.

Data obtained in this study were analyzed qualitatively and descriptively. This qualitative technique was used to analyze the results of the Student Questionnaire and Achievement Tests. Descriptive techniques are used to analyze Observation Sheets to describe the constraints faced.

In this study, students are given 4 multiple choice questions to get students' responses. From the results, the mean of data is calculated, then it is classified into five classes. The categorization of problem solving abilities is calculated using the following formula on Table 1, where $M=(\text{maximum score}+\text{minimum score})/2$, and $S=(\text{maximum score}-\text{minimum score})/6$ [6]. The criteria used are presented in Table 1.

| Interval of Mean | Interval of Mean | Category |
|------------------|------------------|----------|
| $\bar{x} \leq M - 1,5S$ | $\bar{x} \leq 1,75$ | Very poor |
| $M - 1,5S < \bar{x} \leq M - 0,5S$ | $1,75 < \bar{x} \leq 2,25$ | Poor |
| $M - 0,5S < \bar{x} \leq M + 0,5S$ | $2,25 < \bar{x} \leq 2,75$ | Enough |
| $M + 0,5S < \bar{x} \leq M + 1,5S$ | $2,75 < \bar{x} \leq 3,25$ | Good |
| $\bar{x} > M + 1,5S$ | $\bar{x} > 3,25$ | Very good |

To analyze the achievement test, students did the problem solving test which has maximal score 4 for each problem. The mean of score is calculated, then it is classified into five classes. The categorization of problem solving abilities is calculated using the following formula on Table 2, where $M=(\text{maximum score}+\text{minimum score})/2$, and $S=(\text{maximum score}-\text{minimum score})/6$ [6]. The criteria used are presented Table 2.

| Interval of Mean | Interval of Mean | Category |
|------------------|------------------|----------|
| $\bar{x} \leq M - 1,5S$ | $\bar{x} \leq 1,00$ | Very poor |
| $M - 1,5S < \bar{x} \leq M - 0,5S$ | $1,00 < \bar{x} \leq 1,67$ | Poor |
| $M - 0,5S < \bar{x} \leq M + 0,5S$ | $1,67 < \bar{x} \leq 2,33$ | Enough |
| $M + 0,5S < \bar{x} \leq M + 1,5S$ | $2,33 < \bar{x} \leq 3,00$ | Good |
| $\bar{x} > M + 1,5S$ | $\bar{x} > 3,00$ | Very good |

3. Research Results and Discussion
The worksheets are arranged in a simple format because it is adjusted according to students. The worksheets contain a few basic materials and activities. In the beginning, it is presented as one type of transformation or apperception containing material that will be used as a basic of material for
discussion. This is so students are given the opportunity to connect various concepts. The Figure 1 is excerpts from this section of the worksheet.

![Figure 1. Basic material in the worksheet](image)

Some activities are presented in the worksheet. Some of the initial activities are to introduce the concept and to provide exploration and discovery activities for students. The students find the properties of a type of transformation. In some of these Activities, a Geogebra file has been provided, to give examples and an illustration of how to use Geogebra. This is to overcome the existence of students who are still having difficulty using and making Geogebra files. This fact is consistent with the results of the student response questionnaire, some of which still have difficulties in using Geogebra. These activities are equipped with Geogebra files. The Figure 2 shows an example of this section.
The next activity uses Geogebra files created by students themselves. In some further exploration activities, students are asked to make their own Geogebra files. Apart from being intended to train students' skills in using Geogebra, it also provides opportunities for students to design how to use Geogebra as well as to solve problems. The Figure 3 gives an example of activity where students are asked to create their own Geogebra file to find some properties of one type of further transformation.

The worksheet also contains activities which do not use Geogebra files, for example drawing manually. Manual drawing activities are also carried out to develop students' skills. The Figure 4 is the example of this activity.

In the final section, activities in the worksheet are designed to develop problem-solving skills. The activity consists of some problem solving questions. Some problem solving problems are also not equipped with images in order to develop abstract abilities that are appropriate to the development of
learning geometry. The Figure 5 gives an example of activity where students solve problem-solving problems.

![Figure 5. Problem solving activity](image)

These worksheets are implemented in learning for topics Translation and Half Turn. Students discuss in groups working on activities worksheet. Several groups present the results of their discussion. The lecturer and students discuss the results of the presentation. How students doing discussion is shown in The Figure 6. The Figure 7 shows how students present their results of discussion.

![Figure 6. Students doing discussion](image)
Figure 7. Students present their discussion results

After the worksheet has been tested in learning, students are asked to fill in questionnaires in response to lectures using the worksheet that has been prepared. Student response questionnaire is used to explore students’ opinions viewed from aspects: 1) Students' responses to learning using Geogebra-assisted worksheet, 2) Students' opinions on practicing problem solving skills, 3) Ease and assistance, 4) General responses, and 5) Constraints.

Table 3. The score of students’s responses

| No | Aspect                                              | Mean | Criteria   |
|----|-----------------------------------------------------|------|------------|
| 1  | Student’s responses to learning by using Geogebra-assisted worksheet | 3.30 | Very good  |
| 2  | Student’s opinion towards practicing problem solving skills | 3.40 | Very good  |
| 3  | Ease and assistance                                 | 3.32 | Very good  |
| 4  | Total Mean                                           | 3.33 | Very good  |

From the open questionnaire the following responses were obtained. Students gave positive responses to the use of Geogebra-assisted worksheet. They find it helpful and easy for them to visualize and understand the material. The obstacles that occur in learning are students are not fluent using Geogebra and not all students use laptops. Input from students is more explained in using and interpreting the results of Geogebra's output.

After four meetings with learning using the worksheet, a test was held to measure problem solving skills. The problem solving ability test consists of three problem solving questions for Translation and Half Turn topics. It is obtained an average score of problem solving skills is 2.34 so that it is in good criteria.

This is possible because students learn more independently by conducting exploration activities, students are accustomed to finding their own nature, and solving several problems in group discussions. By conducting exploration activities, students will be trained to understand problems and expand opportunities to develop their ideas. This will be useful when students design and explore ideas to solve problems. Merrilyn Goos said that mathematical knowledge is not fixed but fluid, constantly being created as the learners interact with ideas, people, and their environment. When technology is part of this environment, it becomes more than a substitute for mathematical work done
with pencil and paper. Consider, for example, the way in which dynamic geometry software allows students to transform a geometric object by “dragging” any of its constituent parts to investigate its invariant properties. Through this experimental approach, students make predictions and test conjectures in the process of generating mathematical knowledge that is new for them [4].

Nevertheless, some students still cannot find ideas and design, and write in detail the steps in solving problems. This especially occurs when students solve problem related analyze figure and write the steps to solve it. This result is similar with Posamentier and Stepelmen statement, the problems in geometry include: 1) Proving theorem or various consequences of a geometry situation systematically (using Euclidean geometry, using algebra, arithmetic, analytic geometry, or vectors), 2) Drawing geometric figure, and 3) Determine the size of geometric elements in problematic situations [5].

With the support of the superiority of Geogebra software, students will be helped in terms of visualizing the change in location and shape changes of geometric objects due to the transformation. This will help improve students' understanding of the material. Geogebra provides students in various visualization ability levels to learn geometric concepts and to explore relationships easily[10].

In addition to help students, by using technology, students become more interested and happy to attend lectures. This resulted in students more enthusiastic about attending lectures. This is supported by the results of student responses to the lecture questionnaire. Farrel, Makar, and Confrey said that technology can change the nature of school mathematics by engaging students in more active mathematical practices such as experimenting, investigating and problem solving that bring depth to their learning and encourage them to ask questions rather than only looking for answers [4]. The results are not different with Bature’s results. He found that 1) Effective use of ICT tools in teaching and learning of mathematics improves students’ performance and achievements; 2) Effective use of ICT tools enhances teaching and learning of mathematics and improves students’s problem-solving skills; and 3) Effective use of ICT tools motivates and makes students interested in learning mathematics [9].

NCTM believes that the use of technology can enhance deeper understanding, because technology can give students the freedom to discover, explore, and make conclusions about mathematical ideas; thus allowing students to act and think as mathematicians through strengthening students' conceptual understanding [1].

Although students find it helpful to visualize and understand the concept of transformation, students still have difficulty in using, creating, and interpreting the appearance and output of Geogebra software. However, in general students gave positive responses and felt helped by the use of this Geogebra-assisted worksheet.

4. Conclusion
The Geogebra-assisted worksheet is arranged in a simple format because it is considered appropriate for students. It meets the good criteria based on the results of tests of problem solving abilities, which are included in either category with a score of 2.34 from the maximum score. 4. The worksheet also meets very good criteria based on the results of student response questionnaires with a score of 3.33 from maximum score 4. The constraints faced in developing and implementing Geogebra-assisted worksheet are that students are still not fluent using Geogebra software and are still having difficulty interpreting Geogebra's appearance and output.

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