The effectiveness of an autograph-assisted problem based learning model for improving high school students’ learning outcome on graphics functions

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Abstract. Students’ learning outcomes can be enhanced through tasks that require students to relate images in their daily life to mathematical graphs. However, students find it difficult when they draw mathematical graphs by using pens or pencils. Therefore, they need a digital tool to assist them. This study aimed at developing a digital tool for teaching and learning of graphics functions. It adopted Plomp’s model of design research that consists of three phases: (1) preliminary research (2) prototyping phase, and (3) assessment phase. It is important to highlight that this paper presents the assessment phase of the study. Data were collected to determine the effectiveness of Autograph-assisted problem-based learning model. Participants of this study were 17 year-ten students from a high school in Banda Aceh city, Indonesia. Data were obtained through student’s worksheet and questionnaire, and it was analysed descriptively. The findings showed that 88% of the students achieve learning objectives and 90% of them had positive responses toward the leaning.

1. Introduction
Graph function is one of the mathematics topics at Year 10 and this subject is applied to many other fields such as physics. However, students find this topic difficult to master. Most students have difficulties in this subject as they have lack understanding of the subject particularly graph function [1]. Furthermore, based on the interview conducted by the researchers to one of the mathematics teachers in a high school in Banda Aceh, it was found that students did not fully understand the concept of graph function which resulted most of them were not able to solve mathematical problems associated with graph functions. In addition, students have difficulties in applying formulas and solving problems related to applications of graph function in everyday life.

Several studies have been conducted to develop learning tools using Autograph software for learning various topics [2,3] such as linear programming [4] and calculus [5]. However, there is no research that developed the learning tool for teaching graph functions through Project-Based Learning (PBL) assisted with Autograph. Thus, it is necessary to develop such teaching tools to assist students in the learning process.

In the learning, students are required to explore their ideas and strategies in solving mathematical problems by using Problem Based Learning (PBL) model. In the view of constructivism, learning aims to help students to understand and apply knowledge. They must work together, find concepts by themselves, and try with their ideas [6]. The PBL model is one of the constructivism learning models, which builds the concepts of students’ understanding with real experience and through the process of collaboration in building their understanding and being able to convey the ideas that they find through
the collaboration process [7]. PBLs are designed to help students develop their thinking skills, problem-solving skills, intellectual skills, and the model also stimulate students to become self-sustaining, as well as autonomous learners [8]. The PBL model can develop specific skills, including the ability to think critically, to analyze and solve complex and real-world problems [9]. Moreover, this model can help students to find, evaluate and use resources appropriately as well as to work together, to demonstrate effective communication skills, and to use intellectual knowledge and skills in order to keep the students highly motivated to follow the learning process [9]. One way to maximize student motivation is by using software as a learning media. One of the appropriate mathematical software is the Autograph software.

Through Autograph-assisted learning, students can do an exploration, investigation, and discovery [10]. Students can test more samples in a short time to prove the results that they obtained by pen and paperwork. As a result of their experiments, students are able to find, construct and draw a conclusion about the concepts of the Graph Function to determine the equation, and finally understand how to draw the equations of a graph correctly. Autograph Software provides quite complete features including geometry and algebra. The software also has 2D and 3D graphics capabilities for topics such as transformation, vector, and derivatives [11]. In addition, it can be utilized to draw statistical graphs, functions, and vectors as well as to alter the shape of an object or geometry shape.

Based on the above description, the problem formulation in this research is how effective the use of autograph assisted problem-based learning model for high school students’ learning outcome on graphics functions.

2. Method
This study adopted Plomp’s model of design research that consists of (1) preliminary research (2) prototyping phase, and (3) assessment phase. We collected data to examine the effectiveness of Autograph-assisted problem based learning model on learning graph functions. In total, 17 students from grade 10 of a high school in Banda Aceh participated in this study. Instruments used in this were tasks and questionnaire, and data were analysed descriptively. There were three lessons delivered during this study. In the first lesson, students were asked to draw graphs of a linear function while in the second lesson students were assigned to create graphs of quadratic functions. Moreover, in the last lesson, students were asked to draw graphs of trigonometric functions. In order to determine the effectiveness of the tool, we set the following criteria. Learning tools are considered effective when 85% of the students get a score of completeness criterion (75). On the other hand, the developed learning instruments fall into category positive when 80% of students respond happy, new, interested, obvious, attracted categories.

3. Result and discussion
In this section, we elaborate on the results and discuss them with related literature. We present student learning outcomes and their perceptions of learning activities respectively. Regarding their learning outcome, first, we present students learning outcome in groups, which is then followed by a discussion of individual students learning outcomes.

3.1. Students’ learning outcome
As mentioned earlier, this study looked at students’ learning outcome in groups and students’ individual learning outcome. Both aspects are presented in the following subsections.

3.1.1. Students’ learning outcome in groups
Assessment of student learning outcomes in groups is by investigating students during group work. The results of student learning in groups are presented in Table 1.

Table 1 shows that students in groups I, III and IV satisfied very good criteria whereas students in group II met good criteria. Overall, from the student's worksheet, it showed that the students were able to use and completed the developed worksheet.
Table 1. Scores on student's worksheet

| Group | Scores of student’s worksheet | Mean Score | Criteria |
|-------|-------------------------------|------------|----------|
| I     | 90 89 95                      | 91.33      | Very Good|
| II    | 85 90 93                      | 89.33      | Good     |
| III   | 92 95 95                      | 94.00      | Very Good|
| IV    | 87 93 95                      | 91.67      | Very Good|

The learning outcomes falls into the good category that indicates a positive result. This result is consistent with [12] that suggest that problem-based learning is more effective in improving learning achievement. This is due to PBL has the following advantages: (a) Challenges students' ability as well as provides satisfaction to find new knowledge for students, (b) Increases student's motivation and learning activities, (c) Helps students in transferring their knowledge to understand real-world problems, (d) Assists students to develop new knowledge and be responsible for their learning, (e) Develops students' critical thinking skills and develop their ability to adapt to new knowledge, (f) Provides opportunities for students to apply the knowledge they have in the world (g) Develops students' interest in continuous learning even when learning in formal education has completed, (h) Facilitates students in mastering the concepts to solve real-world problems [13]. Students’ learning outcomes in groups are required when students complete the student's worksheet. In this study, at the learning stage, it helps independent and group mobilization.

3.1.2. Students’ individual learning outcome

Students’ individual learning outcomes were obtained through tasks at the end of the lesson. Regarding students’ individual learning outcomes, 88% of the students received passing grades and 12% were unable to reach the standardized grade. It means that students were able to relate the given images to their daily life in order to find the graphics function. Therefore, it can be concluded that students’ learning outcome on graphs function fall into the good category. Examples of students’ works are presented in Figure 1 and Figure 2.

Figure 1. Graph of a trigonometric function

Figure 2. Student’s answer
A function that matches the image is \( y = -\cos 4.5x \). Furthermore, the minimum value on the graph is -1 while the maximum value on the graph is 1. In addition, period of the graph is \( 2\pi \) and amplitude is 1. Amplitude = 1

It can conclude that students were able to determine the trigonometric function of the image that they find in their daily life, determine the maximum and the minimum value of the trigonometric function, determine the period and determine the amplitude of the graph. Furthermore, for another problem, we can see in Figure 3.

![Figure 3. Graph of quadratic functions](image)

The function of the image is \( y = -8.2x^2 + 9 \). Moreover, the highest value of the function is 0.9. The graph of the quadratic function is \( y = -8.2x^2 + 9 \) that is closed when \( a < 0 \).

According to Figure 4, we conclude that students were able to find the quadratic function of the image, and determine the highest point of the graph. This result is consistent with [11] that reveal that Autograph software is effectively used in teaching quadratic functions in high school.

3.2. Students’ perception of the lessons

At the end of the lessons, students were given the questionnaires. The results of the questionnaire show that 90% of the students had positive responses to learning with Autograph. They also stated that the language used in Autograph guideline, student's worksheets and student tasks are clear and interesting.

These positive responses are ranging from comments on the process of learning activities to comments on learning media that have been utilized. Students were happy with the learning that had taken place. Students also commented on the use of the software and the motivation in learning.

Examples of students’ responses are presented in Figure 5 and Figure 6. Based on the students’ comments, it shows that learning by using technology can increase students’ interest and motivation. These results are consistent with [14] which states that technology as one of the mathematics learning media can bring new changes that greatly assist students in bridging the abstract world of mathematics and real-world students.
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Autograph helps me in learning of trigonometry.

Figure 5. Student’s response to the use of autograph software

Learning with Autograph software makes me happy and increases my motivation.

Figure 6. Student’s response to the use of autograph software

4. Conclusion
In concluding this paper, based on the findings of this study, we suggest that Autograph software is an effective tool to assist students in learning of the graphics functions through problem-based learning. Moreover, students had positive responses toward the learning. Therefore, it indicates that this tool is potential to become learning media in teaching and learning of graph functions. However, in order to be more effective, we suggest that students need to be supplied with adequate ICT infrastructures such as computers or laptops. Finally, it needs further study to investigate the use of this tool in teaching and learning other topics of mathematics through problem-based learning.

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