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Learning dilation through *Lawang Sewu* context

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Abstract. Geometry understanding is a significant aspect of studying geometric transformation. Besides, geometry is the basis for most mathematical and other topics. However, geometry is nonetheless a challenging material for students, particularly the dilations of geometric transformation. This case may be due to a lack of activity requiring students to relate geometrical principles to their environment. Therefore, this study aims to establish a learning trajectory using the *Lawang Sewu* historical building as the context to help students understand the idea of dilation. The learning approach used in this study was Realistic Mathematics Education, named PMRI in the Indonesian edition. The subject of the study is the ninth-grade students at one of the junior high school in Semarang, involving six students who were selected as diverse students. The methodology applied consists of three stages of design research: preliminary design, design experiment, and retrospective analysis. Additionally, this study reveals only the findings of the design experiment and the pilot experiment in particular. Students' learning activities involve three activities, such as identifying the elements of *Lawang Sewu* that represent dilations through interactive video, determining the result of dilations and scale factor, and solving problems of dilations. Studies have shown that using the *Lawang Sewu* historical building context could assist students in improving their comprehending of the dilation concept. Furthermore, this study could be an inspiration to explore another local wisdom that can be a context in learning mathematical concept.

1. Introduction

Transformation geometry material is one of the mathematics materials taught at the Junior High School level. Transformation content is one of the most significant resources for students to learn [1,2]. Transformation geometry is essential since numerous transformation ideas are utilized in daily life [3,4] and offers a valuable visual source for recognizing arithmetic, algebraic and statistical concepts [5]. In addition, Edwards [6] confirms that the transformation of geometry offers students sufficient potential to enhance their ability to visualize space and think geometrically. Transformation content involves reflection, translation, rotation and dilation. However, material transformation is indeed challenging for students, particularly dilation [7].

Students' difficulty in transformation geometry mainly is to decide the sides of the two triangles correspond and the factor of scale [8]. In line with that, Xistouri, Pantaszi, and Gagatsis [9] also report that students' problems in dilations are recognized as the parameters of a specific transformation and form an idea of a transformation. Besides, according to Noto et. al. [10] the empiricism of transformations includes five types of barriers, namely: a) barriers to recognizing the notion; (b) representation of the geometric object; (c) identification of the theory; (d) comprehension of the issue; and (e) mathematical evidence.

The learning problems of the students cannot be distinguished from the previous learning experience. In this context, it needs to be tackled, particularly in the learning of dilation material in the practice of learning mathematics. Studying mathematics, which has been achieved up to now, appears to concentrate on the achievement of curriculum objectives. The learning process still places the teacher as a source of knowledge, and the learners involved in the study process were quite frequently located. It makes mathematical concepts challenging for students to be comprehended [11,12].

Based on the above issues, learning dilation needs to be planned more practically and be meaningful. Researchers conducted a design learning study that develops a series of activities using the Indonesian Realistic Mathematics Education (PMRI) approach that recognizes the relevance of concepts. The Indonesian Realistic Mathematics Education, or PMRI, is an efficient and practical approach to studying mathematics [13]. Furthermore, PMRI has been applied to improve student attention, behaviours and low skill of students [14-20]. The context function in Indonesian Realistic Mathematics Education is the beginning stage for students in developing mathematical grasp and as a source of mathematical applications [21,22].

In this study, the authors choose the context of the *Lawang Sewu* since the historic building could characterize dilation of transformation geometry that had not been utilized as a context for learning mathematics previously. The authors conducted this study based on the above background to encourage students to explore the concept of dilations based on *Lawang Sewu* historical building in Central Java, Indonesia, in order to develop a learning trajectory that consists of a mathematical goal, a progression of students' thinking process, and instructional activities. In addition, this study aims to describe the learning trajectory of geometric transformation of dilation using the historical building of *Lawang Sewu* as a context developed from an informal to a formal level.

2. Methods

The methodology used in this research is a design research method that aims to establish a theory of how students learn and whether to enhance the learning process [23]. Design research has three phases that comprise a cyclical process, including in each phase and throughout the entire design research process, namely (1) preliminary design, (2) experimental design, consisting of two phases, pilot experiment and teaching experiment, and (3) retrospective analysis [24]. However, this study was restricted to the experimental design pilot process.

The subjects of this study were six ninth-grade students of ninth grade of SMP N 6 Semarang, Central Java. The selection of research subjects was based on students' ability to learn mathematics and student activity during the implementation process. Thus six study participants with heterogeneous abilities, two high-ability students, two medium-ability students, and two low-ability students, were chosen based on their previous test result and confirmed by the teacher. There are several data collection, namely observation sheet, video recordings activities in groups, collecting student data from students activity sheet, and students interview records about students responses on their worksheet.

3. Result and discussion

The results obtained in this study are the learning trajectory of dilation material using the context of the *Lawang Sewu*. This learning trajectory consists of three activities. The first activity is identifying the elements of *Lawang Sewu*, which represent dilations through interactive video. Furthermore, the second activity is determining and drawing the shape result of dilation. The third activity is to solve problems of dilation. Based on activities that have been designed, students are able to master the understanding of the concept of dilation easily using the *Lawang Sewu* context, which can be viewed from the results of students' answers on the Student Activity Sheet (SAS), final tests, and interviews. For more details, the following researchers explain in detail the results of this study.

3.1. Activity 1: Identifying the elements of Lawang Sewu which represent dilation through interactive video

Before the teacher starts the learning material, the teacher provides apperception material with a question and answer system and asks several students to explain the concept of material that has been discussed previously, namely reflection material. Students were very enthusiastic in this apperception material

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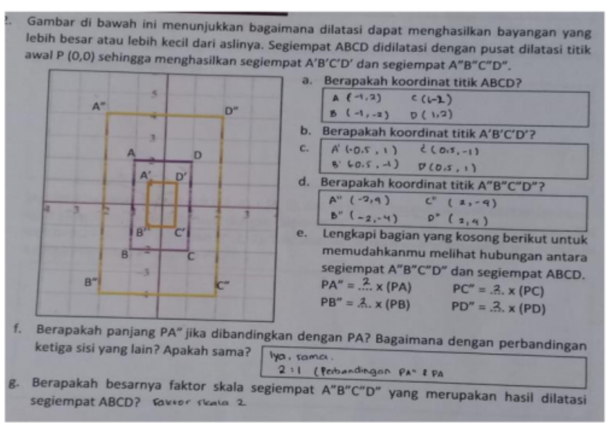
which is shown from students' activeness when doing questions and answers. Researchers provide Student Activity Sheet 1 (SAS 1), which contains several contextual questions. After that, students were asked to watch the interactive video of *Lawang Sewu* to sketch the shape of Lawang Sewu, representing the form of dilation and understanding the concept of dilation. Figure 1 is a description of student activities while watching the *Lawang Sewu* video.

Figure1. Students observing video of *Lawang Sewu*

Students can accurately illustrate the shape of the *Lawang Sewu* building, which depicts dilation and can adequately grasp the concept of dilation. For example, the apparent size of many doors, although in fact all of them have the same size, if we illustrate it on the paper, it looks like the farther, the smaller that can represent dilations form. Also, there is a different size of triangle garden that can represent dilations. From this activity, it can be inferred that students have been able to better grasp the definition of dilation according to the objectives of the first activity.

3.2 Activity 2: Determining the result of dilation and scale factor

Students are expected to find the dilation formula using some construct questions to find the centre of dilation at the origin point and *p* point in this phase. Students in this activity are encouraged to think critically and to be able to solve problems. The students' answers to SAS 2 are shown in figure 2.



2. Gambar di bawah ini menunjukkan bagaimana dilatasi dapat menghasilkan bayangan yang lebih besar atau lebih kecil dari aslinya. Segiempat ABCD didilatasi dengan pusat dilatasi titik awal P (0,0) sehingga menghasilkan segiempat A'B'C'D' dan segiempat A"B"C"D".

a. Berapakah koordinat titik ABCD?

A (-1,2) C (1,-2)
B (-1,-2) D (1,2)

b. Berapakah koordinat titik A'B'C'D'?

c. A' (-0.5 , 1) C' (0.5,-1)
B' (-0.5 , -1) D' (0.5 , 1)

d. Berapakah koordinat titik A"B"C"D"?

A" (-2,4) C" (2,-4)
B" (-2,-4) D" (2,4)

e. Lengkapi bagian yang kosong berikut untuk memudahkanmu melihat hubungan antara segiempat A"B"C"D" dan segiempat ABCD.

PA" = 2 x (PA) PC" = 2 x (PC)
PB" = 2 x (PB) PD" = 2 x (PD)

f. Berapakah panjang PA" jika dibandingkan dengan PA? Bagaimana dengan perbandingan ketiga sisi yang lain? Apakah sama?

Iya, sama.
2 : 1 (Perbandingan PA" & PA

g. Berapakah besarnya faktor skala segiempat A"B"C"D" yang merupakan hasil dilatasi segiempat ABCD? faktor skala 2

Figure 2. Student's response on SAS 2

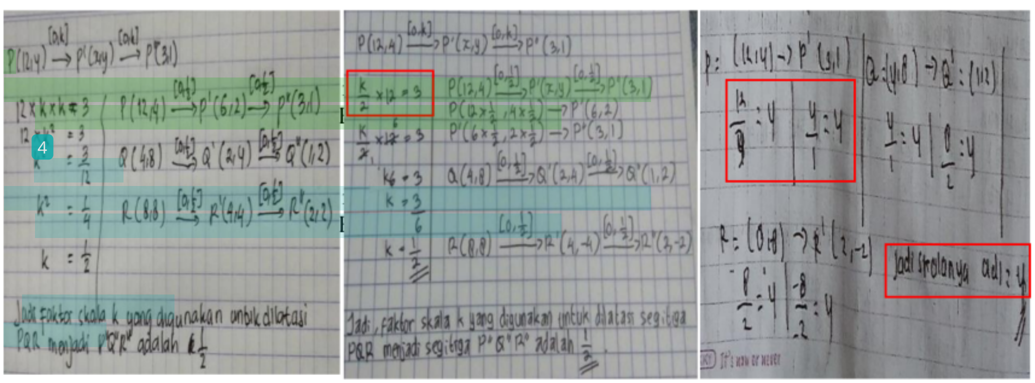
Furthermore, students were able to solve problems by engaging with groups based on students' answers in SAS 2. The student determines the coordinate of A'B'C'D' and A" B" C" D" as the result of dilation with the centre point of P (0,0). Then, students also could found the scale factor of dilation by comparing the coordinate of the original shape and the resulting shape of dilation. In addition, the interview script can be seen as follow.

researcher : *"how can you find each coordinate point of these shapes?"*
student : *"I find those each coordinate point by looking at the given shape and the result of dilation"*
researcher : *"good, then can you find the scale factor of this dilation?"*
student : *"yes, I can"*
researcher : *"good, how can you find that?"*
student : *"by comparing the coordinate point of the origin shape and the result of dilation"*
researcher : *"good, what is the ratio of PA" to PA? is it similar to the ratio of another side?"*
student : *"the ratio of PA" to PA is 2:1, and it is similar to the ratio of another side"*
researcher : *"so, what is that scale factor?"*
student : *"the scale factor of that dilation is 2"*

From the interview, the students can determine the coordinate of the shape result of dilations and also its scale factor. Written results and interviews show the achievement of the goals for activity 2.

3.3 Activity 3: Solving problems of dilations

Students were asked to work on Student Activity Sheet 3 (SAS 3) in this activity, which contains contextual issues related to dilations. Students discuss in groups to be able to solve contextual problems that were given. Figure 3 is the student's response to activity 3.



(a) the high abilities student (b) the middle abilities student (c) the low abilities student

Figure 3. Student's responses on SAS 3

The student with high abilities in mathematics was able to solve problem correctly. She could use the formula properly to find scale factor in the case problem of twice dilations and determine the correct answer, that the scale factor is $\frac{1}{2}$ (figure 3a). The student with middle abilities in mathematics was also able to find the correct answer. She could find the scale factor is $\frac{1}{2}$, but the procedure used was still incorrect (figure 3b). The student with low mathematics ability could not figure out the problem and produce the incorrect procedure and answer (figure 3c).

Based on the analysis of students' worksheet, observation and interview result, using the historical context building of Lawang *Sewu* could help students recognize mathematics and the connection regarding mathematics in daily life and help students grasp the concept of dilation material in transformation. This is aligned with [15-17,21] that the use of context in mathematics learning is indeed beneficial for students in developing significant correlations among context and mathematical ideas to foster the development of mathematical thought by students.

This study based on the principles and five characteristics of the PMRI [22,24], including (a) the use of contexts, in achieving this study, the *Lawang Sewu* historical building has been chosen as a learning context, (b) the use of models and symbols for progressive mathematics, the use of models and symbols for learning in order to guided students to solve problems throughout a process of problem-solving. There were four levels of emergent modelling in this study. The first level is the 'situational level', where students observe a video of the context of the historical building of *Lawang Sewu*. At the second level, namely the 'referential level', students identify and draw the parts of *Lawang Sewu* that represent dilation shapes such as the shape of a triangular garden and many doors that look smaller even though it is actually the same size. Some examples of these shapes serve as a starting point for studying the concept of enlargement and reduction in dilation. In the third stage, namely the 'general level', students use a Cartesian diagram to generalize the dilation formula and develop an understanding of scale factors. At the last stage, namely the 'formal level', students develop their informal knowledge into a formal concept of dilation. This is in line with Wijaya et. al. [25], that there are four levels of emergent modelling, namely situational level, referential level, general level, and formal level. Then (c) using the student's contribution and construction, during the learning process, teachers allow students the right to express queries and engage in discussion, it can be seen through the multiple responses that students provide in solving the problem, (d) interactivity, interactivity not only between student to student in a group but also among teacher and students interact in class, the type of interaction might be in the form of conversation, description, communication, and evaluation; (e) intertwining mathematics principles, aspects and units, which ensures the mathematics taught to students would be more significant as it applies to other learning topics.

4. Conclusion

The learning trajectory resulted in this study consist of three activities, namely: identifying the elements of *Lawang Sewu*, which represent dilation through interactive video, determining the coordinate point of the shape result of dilation and scale factor, and solving problems of dilation. The results of this research indicate that, by using *Lawang Sewu* historical building context, students could be encouraged to understand the concept of dilation through a series of designed activities.

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