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HYOTHETICAL LEARNING TRAJECTORY ON DILATION MATERIAL USING REALISTIC MATHEMATICS EDUCATION AND GEOGEBRA MEDIA

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ABSTRACT

Dilation is a part of geometry transformation that is useful for students. However, students often have difficulty in understanding dilation material. Therefore, this study aims to develop a learning trajectory to facilitate students in understanding dilation material by using the context of *Tedhak Siten* tradition. The research subjects consisted of 32 ninth grade students of SMP Negeri 6 Semarang, which was conducted from August to September 2023. The research method used is design research which consists of three stages, namely preparing for experiment, design experiment, and retrospective analysis. All learning activities were based on the Realistic Mathematics Education approach and supported by GeoGebra media. The results of this study include three learning activities, including: observing the *Tedhak Siten* tradition video to find the properties and definition of dilation, finding the formula and results of dilation, and solving contextual problems related to dilation. From the activities carried out, it can be seen that learning dilation by using the context of the *Tedhak Siten* tradition based on RME and supported by GeoGebra media can help students improve their understanding of the concept of dilation material in class IX SMP Negeri 6 Semarang. In addition, *Tedhak Siten* tradition can be used as a relevant context in learning mathematics.
Keywords: Dilation, Hypothetical Learning Trajectory, Realistic Mathematics Education, GeoGebra

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PRELIMINARY

Dilation is a transformation that changes the size of a shape (reducing or enlarging) with an unchanged shape, remaining as before (Fife et al., 2019; Hada et al., 2021). Learning dilation is very beneficial for students, including being able to improve students' mathematical abilities (Elvi et al., 2021), improve students' visual skills (Cahyaningrum et al., 2023), and improve students' problem solving skills (Ardinata et al., 2020). Despite its many benefits, dilation material is still difficult for students to understand (Maulani & Zanthy, 2020; Priciliya, 2021).

The challenges faced by students in learning dilation involve difficulties in understanding the concept of dilation (Surgandini et al., 2019), difficulties in using the dilation formula (Maulani & Zanthy, 2020), and difficulties in determining the position of objects after being dilated (Haqq et al., 2019). Behind these student difficulties, of course there are causes that make students have difficulty learning dilation.

The causes of students' difficulties in learning dilation are divided into two, namely internal aspects and external aspects (Arifin, 2023). Internal aspects include students' lack of interest in learning and the assumption that math is difficult to understand (Meutia, 2022). Meanwhile, external aspects can include inappropriate learning methods, lack of application of learning media, and an unsupportive learning environment (Hubulo et al., 2022). Both factors, if left unchecked, will have an impact on low student understanding (Diana et al., 2020). So a solution is needed to solve these problems.

The solution to overcome students' lack of interest in learning dilation is to use props and technology in learning and link learning with students' real lives (Hanipah et al., 2022). Meanwhile, to improve the learning process in the classroom, teachers need to make learning designs by choosing appropriate learning methods (Wulan et al., 2022), utilizing learning media to assist the learning process (Fatoni & Septiadi, 2021), and getting students directly involved in learning (Fatoni & Septiadi, 2021).

Therefore, it is necessary to design dilation learning using the Realistic Mathematics Education (RME) approach. RME is a mathematics approach that leads to understanding mathematics from students' real lives (Nurcahyansi, 2023). RME has several characteristics, including the use of context or contextual problems, applying models that emphasize informal solutions before adopting formal approaches, linking mathematical topics to each other, applying interactive methods in mathematics learning, and giving value to various answers and student contributions (Yonathan & Seleky, 2023). RME has been proven to improve students' concept understanding (Hubulo et al., 2022), increase student engagement and learning outcomes (Priciliya, 2021), and improve problem solving skills (Apriyanti et al., 2023).

One of the characteristics of RME is using context. Context has an important role in learning, one of which makes mathematics more interesting and improves teacher learning process activities (Hubulo et al., 2022). Some contexts that have been used in previous studies that have proven to be able to improve student learning outcomes include traditional games (Rahmasari et al., 2023), folklore, legends, community customs (Nursyahidah, et al., 2020), puppet stories (Arbowo et al., 2018), and historical buildings (Fahrurozi et al., 2018; Susanti et al., 2023).

A suitable context for dilation material can be found in the *Tedhak Siten* tradition. This tradition is part of Javanese culture which is carried out when a child first sets foot on the ground. This tradition is carried out so that the child can develop into a successful, independent person, and has the ability to overcome all temptations and obstacles in his life (Endarwati et al., 2022). The equipment used in the Tedhak Siten tradition includes seven-color *jadah*, *jenang bluwok*, *tumpeng* rice, market snacks, ladders, chicken cages, and flowers (Syahira et al., 2022). This tradition was chosen because the equipment in the *Tedhak Siten* tradition is able to represent dilation material, one of which is a chicken cage.

The learning media used in this research is GeoGebra. GeoGebra is an interactive math application that is used for the learning process of mathematics, covering education levels ranging from elementary school to university. GeoGebra provides a variety of features, one of which is geometry, and can be used to create constructions with points, lines, and planes (Surbakti et al., 2022). This media will be used to illustrate how dilation occurs in chicken cages. GeoGebra itself is proven to be able to improve students' concept understanding (Hakim et al., 2021), improve critical and creative thinking skills (Elfandi et al., 2023), and increase learning effectiveness (Yunitasari & Hanifah, 2020).

Previous studies on dilation learning have adopted contexts such as *Batik Tulis Sidoarjo* (Lestariningsih, 2017) and the historical building *Lawang Sewu* (Nursyahidah, et al., 2020) by applying the RME approach. The results proved that this approach was effective in improving students' concept understanding and learning achievement related to dilation material. The novelty in this research is the use of the *Tedhak Siten* tradition context for RME-based dilation learning design with the help of GeoGebra learning media.

Based on the explanation above, the researcher conducted research related to the learning trajectory of dilation material for grade IX junior high school students by utilizing the *Tedhak Siten* tradition as a conceptual framework. The learning will be designed into a Hypothetical Learning Trajectory (HLT) which is used to describe the course of learning to achieve learning objective. The main purpose of this research is to design a learning path that can support students' understanding of the concept of dilation by applying the context of *Tedhak Siten* tradition (Acharya et al., 2021).

METHODS

The research method used in this study is design research which consists of three stages, namely preparing for experiment, design experiment, and retrospective analysis (Gravemeijer & Cobb, 2006). The preparing for experiment stage is a stage to prepare everything used for research, such as HLT and ice berg which are used as a guide in learning, Student Activity Sheets (SAS), *Tedhak Siten* tradition videos, GeoGebra media, and research instruments (observation and interview sheets). Where HLT, ice berg, SAS, video, GeoGebra media, and research instruments have been validated by two people, namely accompanying lecturers and mathematics subject teachers of SMP Negeri 6 Semarang.

The design experimentation stage refers to the implementation stage of the research. This stage involves the implementation of the learning design that has been developed in the previous stage. At this stage, researchers collected data from 32 students of class IX D SMP Negeri 6 Semarang. The data were collected in the form of students' mindset or strategy in solving problems through students' responses recorded on the Student Activity Sheet (SAS), observations, and interviews from August to September 2023. At this stage, the researcher assisted by the model teacher implemented learning activities using the researcher's learning design.

Retrospective analysis is a phase that involves evaluating the effects of processes and outcomes, refining teaching materials, developing learning trajectories, and developing local instruments based on theory. This phase allows researchers to identify the successes and shortcomings of the adopted design and make improvements where necessary.

RESULT AND DISCUSSION

The results of this study can be divided into three parts, starting from the preparing for experiment, design experiment, and retrospective analysis stages.

Preparing For Experiment

At this stage, the researcher brainstormed ideas related to the use of *Tedhak Siten* tradition in learning dilation to facilitate students in grade IX. The selection of this tradition cannot be separated from one of the equipment used during the tradition, namely chicken cages. Chicken cages are able to represent dilation learning as well as students are familiar with the equipment.

Figure 1. Chicken Cage

After selecting the context, the next step was to create an ice berg which would later be used as the basis for the preparation of HLT. Ice berg has four stages, namely concrete mathematics, concrete models, formal models, and formal mathematics. The results of the ice berg can be seen in Figure 2 below.

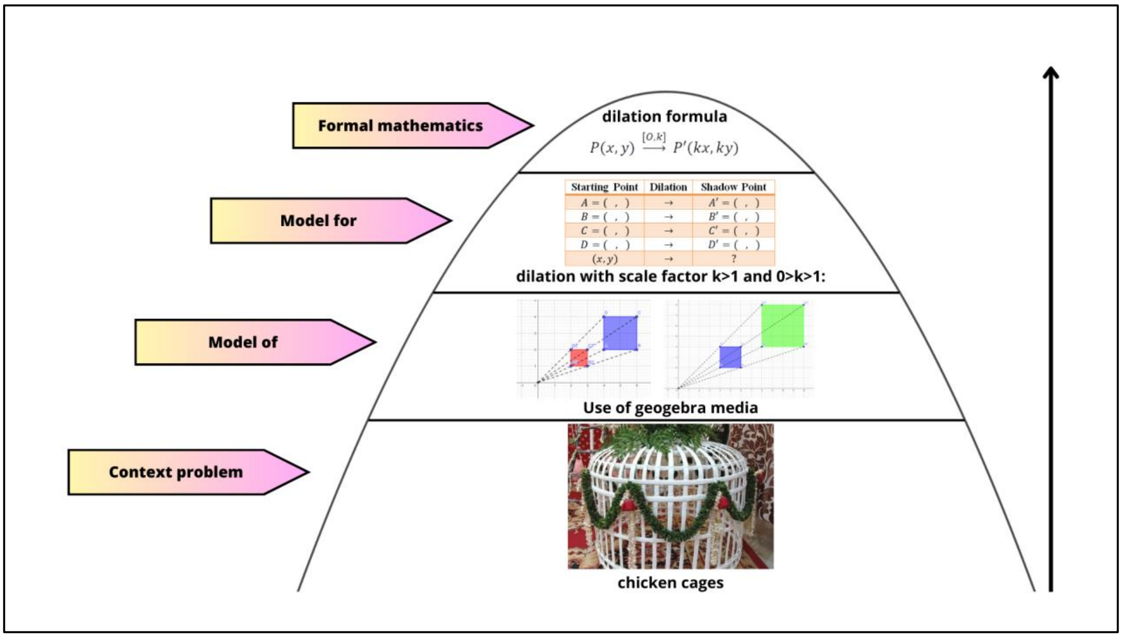


Figure 2. Ice Berg Dilation Material

In the context problem, the selection of chicken cages is very appropriate because it can represent dilatation learning. In the model of, the use of GeoGebra can provide clear illustrations for students related to dilation. In the for model, students are asked to find patterns to find the formula to overcome. In formal mathematcs, students start working on problems using the formula that has been obtained.

The next activity is to develop HLT based on the ice berg that has been made. HLT consists of three stages as in Table 1 below.

Table 1. HLT Dilatation Material

Activity	Objective	Conjecture
Observe a video of *Tedhak Siten* tradition	Find the properties and definition of dilation	• Students can find the properties of dilation • Students can define dilation using their own language
Find the formula and result of dilation	Find the formula and result of dilation	• Students can find the formulas of dilation • Students can find the result of dilation
Solving contextual problems related to dilation	Solving contextual problems related to dilation	• Students can solve contextual problems related to dilation

Design Experiment

Activity 1. Observe The *Tedhak Siten* Tradition Video To Find The Properties and Definition of Dilation

Figure 3. The *Tedhak Siten* Tradition

The activity begins by grouping students into eight groups, where each group consists of four students. Next, the teacher showed a video of the *Tedhak Siten* tradition to start the learning. After the video is finished playing, the teacher conducts a discussion with students regarding the *Tedhak Siten* tradition. The results of the discussion show that students are familiar with the *Tedhak Siten* tradition and there are even students who have been directly involved in the implementation of the *Tedhak Siten* tradition at their neighbor's house. After a brief discussion about the Tedhak Siten tradition, the teacher gave SAS 1 to each group. The SAS 1 was done by the students in order to find the nature and definition of dilation. The students' answers can be seen in Figure 4 and Figure 5 below.

Properties of magnification or reduction
Question: Does the position of the object before and after being enlarged or reduced change?
Iya, Posisi awal dan akhir objek berubah
Student answer: Yes, the initial and final position of the object changes
Question: Does the shape of the object change before and after enlargement or reduction?
Tidak, bentuk awal persegi dan bentuk akhir juga persegi
Student answer: No, the initial shape is square and the final shape is also square.
Question: Does the object before and after being enlarged or reduced in size change?
Iya, Posisi awal dan akhir memiliki ukuran yang berbeda
Student answer: Yes, the initial and final positions have different sizes.

Figure 4. Student Answers Regarding The Properties of Dilation

From Figure 4, it can be seen that students are able to find the properties of dilation through observing the *Tedhak Siten* tadition video, especially the chicken cage..

Question: An object is said to undergo a dilation transformation when....
Objek mengalami perubahan ukuran, baik diperbesar atau diperkecil.
Student answer: The object undergoes a change in size, either enlarged or reduced.

Figure 5. Students' Answers Related To The Definition of Dilation

Figure 5 shows that through the observation of the *Tedhak Siten* tradition video and the discovery of the properties of dilation, students are able to define dilation using their own language. This is reinforced by the following interview results.

Researcher	:	"Based on the video that you have observed, are there objects that have the same shape but different sizes?"
Student	:	"Children and parents' clothes, *tumpeng* before and after cutting the ends, part of the rectangular cage."
Researcher	:	"Is that all?"
Student	:	"From the video shown, our group found only that, sir."

From the explanation above, it is found that through observing the *Tedhak Siten* video, students are helped in finding the properties and definition of dilation. In addition, the observation of the *Tedhak Siten* tradition video can also attract students' interest and attention. This can be seen when the focus of all students' attention is on the video when it is played.

Activity 2. Finding The Formula and Result of Dilation

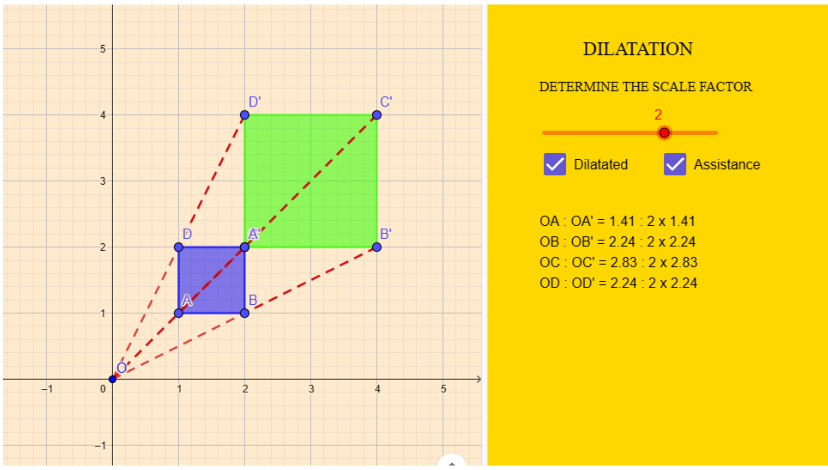


Figure 6. GeoGebra Applet

The learning begins by recalling what objects experienced dilation in the previous meeting, one of which was a chicken cage. This time, students are in groups as before to work on SAS 2 given by the teacher. Before working on SAS 2, the teacher displays parts of chicken cages that have similar shapes but different sizes using GeoGebra. Furthermore, students can operate the applet on GeoGebra to start working on SAS 2. The GeoGebra applet can be seen in Figure 6.

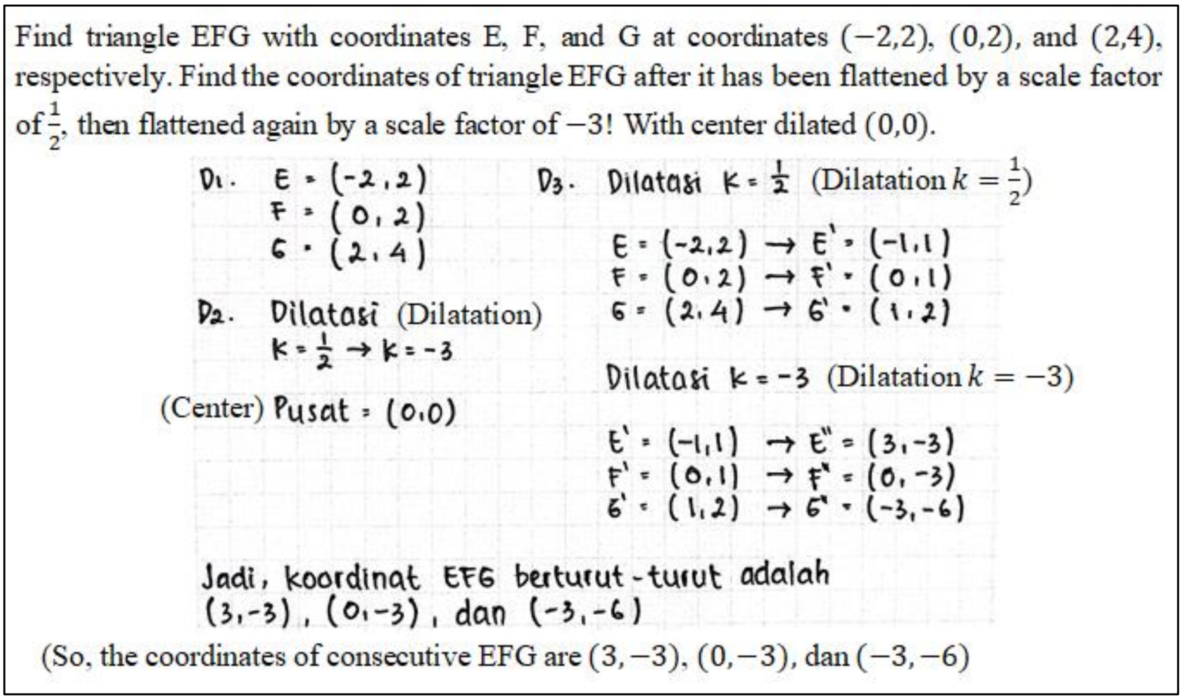
Figure 6 shows that the GeoGebra applet used is not complicated, students only need to slide it in order to work on SAS 2. The student answers are shown in Figure 7 and Figure 8.

Let's observe how the dilation process occurs by filling in the following table

Origin Point	Dilatation	Shadow Point
$A = (1, 1)$	Scale factor = 2	$A' = (2, 2)$
$B = (2, 1)$	Scale factor = 2	$B' = (4, 2)$
$C = (2, 2)$	Scale factor = 2	$C' = (4, 4)$
$D = (1, 2)$	Scale factor = 2	$D' = (2, 4)$
(x, y)	Scale factor = 2	$(2x, 2y)$
(x, y)	Scale factor = k	(kx, ky)

Figure 7. Students' Answers Related To The Dilation Formula

From Figure 7, it can be seen that students are able to read the patterns that occur when an object is dilated. The ability of students to read the pattern does not escape the role of GeoGebra.



Find triangle EFG with coordinates E, F, and G at coordinates $(-2,2)$, $(0,2)$, and $(2,4)$, respectively. Find the coordinates of triangle EFG after it has been flattened by a scale factor of $\frac{1}{2}$, then flattened again by a scale factor of -3! With center dilated $(0,0)$.

D1. E = (-2, 2)
F = (0, 2)
G = (2, 4)

D2. Dilatasi (Dilatation)
k = ½ → k = -3

(Center) Pusat = (0,0)

D3. Dilatasi k = ½ (Dilatation $k = \frac{1}{2}$)

E = (-2,2) → E' = (-1,1)
F = (0,2) → F' = (0,1)
G = (2,4) → G' = (1,2)

Dilatasi k = -3 (Dilatation $k = -3$)

E' = (-1,1) → E'' = (3,-3)
F' = (0,1) → F'' = (0,-3)
G' = (1,2) → G'' = (-3,-6)

Jadi, koordinat EFG berturut-turut adalah (3,-3), (0,-3), dan (-3,-6)

(So, the coordinates of consecutive EFG are $(3,-3)$, $(0,-3)$, dan $(-3,-6)$)

Figure 8. The Tedhak Siten Tradition

Figure 8 shows that with the dilation formula obtained, students are able to solve dilation problems correctly. Not only single dilation, even double dilation, students are able to do it. This is reinforced by the following interview results.

Researcher	:	"How do you do the problem?"
Student	:	"First, determine what is known, namely the coordinates of EFG. Next, because there are two dilations, it is dilated one by one. From the previous result, if a point is dilated, then the result is just the point multiplied by the scale factor. So, for the first dilation, point EFG is simply multiplied by ½ . Then, for the second dilation, the point E'F'G' is simply multiplied by -3."

From the explanation above, it is obtained that GeoGebra plays an important role in helping students understand the concept of dilation. Starting from finding formulas, dilating objects, and even being able to work on problems related to dilation. Observation of the results also indicated that the level of student enthusiasm increased when utilizing learning media.

Activity 3. Solving Contextual Problems Related To Dilation

Transformation consists of four types. Before entering the dilation material, students have learned about reflection, translation, and rotation. In the dilation material, students have found the properties, definitions, and formulas. From the knowledge that has been obtained in the previous meeting, the teacher gives LAS 3 which contains contextual problems related to dilation and is done in accordance with their respective groups. The students' answers on SAS 3 are shown in Figure 9.

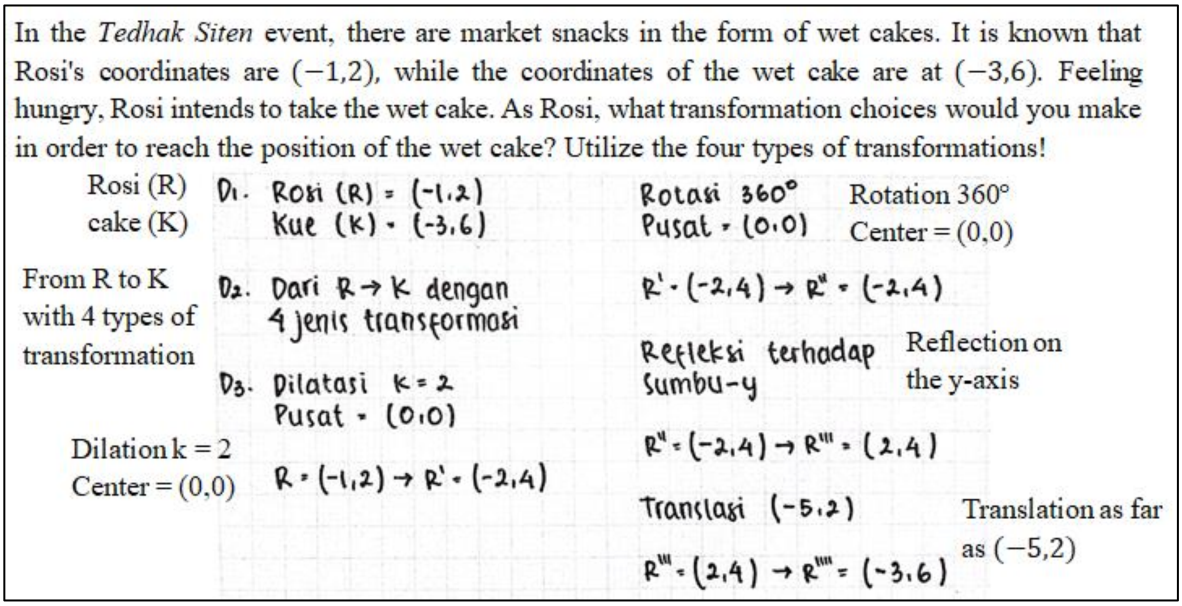


Figure 9. The Tedhak Siten Tradition

Figure 9 shows that through the provision of previous materials, students are able to solve contextual problems related to dilation. This certainly cannot be separated from the characteristics of RME. This is also supported by the following interview results.

Researcher	:	"How do you do the problem?"
Student	:	"Determine the position of Rosi and the wet cake. By using four types of transformation, we have to change Rosi's position to the position of the cake. To begin with, we used dilation and rotation to make it easier for us to reach the position of the cake. Once done, we used reflection and translation. We deliberately used translation at the end because translation can change the position of a coordinate to all coordinates, especially the cake."

From the explanation above, students' success in solving contextual problems cannot be separated from the use of the RME approach which emphasizes informal solving before adopting formal approaches, linking mathematical topics to each other, applying interactive methods in mathematics learning, and giving value to diverse answers and student contributions.

Retrospective Analysis

The HLT shown in Table 1 serves as a guideline to achieve the learning objectives. HLT is used to understand and anticipate problems that students may encounter in the learning process. In addition, the HLT was compared with the data obtained to explain the method and thought process of students in understanding the concept of dilation using the context of *Tedhak Siten* tradition.

The results of students' answers are in accordance with the researcher's expectations, starting from students being able to find objects that experience dilation, the properties of dilation, and the definition of dilation through observing the Tedhak Siten tradition video. Furthermore, students were also able to find the formula and results of dilation through the utilization of GeoGebra learning media, and students were able to solve contextual problems related to dilation through the RME learning approach.

The drawback during this research is that there is a slight disturbance in the android-based GeoGebra learning media. The autosave feature on GeoGebra makes the android slow and quite time consuming which makes learning less effective. For the second cycle, researchers will fix the problem by combining GeoGebra with the Gform or Canva platform..

Early activities showed students' ability to identify objects that experience dilation, understand the properties of dilation, and find the definition of dilation using their own language. The application of the *Tedhak Siten* tradition context, especially involving confinement equipment, proved effective in helping students understand the properties and definition of dilation. This finding is consistent with research by (Lestari et al., 2021; Refugio, 2018), which highlights the important role of context in supporting student understanding. Research by (Sari et al., 2022) said context can arouse students' interest and enthusiasm for learning.

In the second activity, students managed to find the formula and the result of dilation. The use of GeoGebra learning media provides real visualization for students and increases students' enthusiasm and motivation in the learning process. These results are consistent with research by (Handayani & Sulisworo, 2021; Schaver, 2019), which states that the use of GeoGebra can improve students' understanding of concepts. (Kusuma & Utami, 2017) also noted that GeoGebra can increase students' enthusiasm, motivation, and involvement in learning.

In the third activity, students successfully solved the contextual problems given. This success can be attributed to the connection of the problem with the previous activities that apply the RME approach. Students can understand the concept of dilation well through the RME approach, which is also recognized by (Priciliya, 2021; Uyen et al., 2021) as a relevant and meaningful learning approach. (Aprilianto & Sutarni, 2023) also emphasized that the RME approach provides opportunities for students to improve critical thinking skills and student learning outcomes.

CONCLUSION

The result of this research is the development of HLT for dilatation material by utilizing the context of *Tedhak Siten* tradition, which is supported by GeoGebra media to improve students' understanding and create meaningful learning. The resulting learning path consists of three activities, namely observing the *Tedhak Siten* tradition video to find the properties and definitions of dilation, finding the formula and results of dilation, and solving contextual problems related to dilation.

This research confirms that through a series of activities that have been designed, it can make a positive contribution to students' concept understanding related to dilation material using the context of the *Tedhak Siten* tradition. This finding shows that the application of this method can be an effective alternative for teachers to integrate local wisdom as a context in mathematics learning. In addition, this finding also provides an opportunity for future researchers to continue using local wisdom in mathematics learning.

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