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Designing Hypothetical Learning Trajectories Circle Material with a Realistic Mathematics Education Approach Through the Tampah Context

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ABSTRACT

Tampah is one of the cultural contexts that has the potential as a context for learning mathematics. This study aims to design a Hypothetical Learning Trajectory (HLT) using the Realistic Mathematics Education (RME) approach with tampah as a context to help students understand the relationship between the central angle and the circumference of a circle. This study uses a design research method that includes three stages, namely initial design, experimentation, and retrospective analysis. The results of the study showed three main stages. in the first stage is, the design, the researcher conducted a literature analysis and compiled the HLT. In the second stage, experimental design, in the experimental phase in the actual class, students succeeded in solving contextual problems as predicted in the HLT planning. The third stage, retrospective analysis, from the results of the analysis carried out, there were other findings from this analysis, namely the need for a different approach for each group, because the abilities of each group were not completely equal. Some groups were able to immediately solve contextual problems because they had members who understood the material, while other groups needed additional guidance from the teacher. The assumptions designed in the HLT proved to greatly influence the smoothness of the discussion. The results of this study also showed that the RME approach developed in this study met the valid criteria.

Keywords: Circle, Hypothetical Learning Trajectory, Realistic Mathematics Education

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Introduction

The material on the central angle and the circumference of a circle is taught in mathematics lessons in grade XI of high school. According to Lestari in the research of Wahyulina et al (2024), circle material has been known to students since junior high school level, but many students still feel unfamiliar with circle material. Firdausy et al (2023) also argue that many students still have difficulty when working on problems related to circles, especially those involving central angles and circumference angles. The results of observations and interviews with one of the grade XI mathematics teachers. During the observation, the researcher found that many teachers still used conventional learning models, where students only listened to the teacher's explanation. Teachers only use sources from textbooks that only contain a collection of formulas and abstract examples of questions. In the end, students find it difficult to understand and learn the material given

During an interview with one of the grade XI mathematics teachers, it was obtained information that there were several students who were still confused about the circle material, this can be seen from the results of the mid-term exam, most students got exam scores below the Minimum Completion Criteria. In addition, teachers only use Student Worksheets as a learning medium. One of the reasons for the low student scores during the mid-term exam is that the Student Worksheets used by teachers in learning have not fully attracted interest and facilitated active student involvement in learning (Dwiputri et al., 2023). One solution offered to overcome this problem is to innovate contextual learning because the media used is not varied enough. One learning approach that uses contextual problems to show that mathematics is actually very close to students' daily lives is the Realistic Mathematics Education (RME) (Atika & MZ, 2016). This approach is in accordance with the change in the learning paradigm from teacher-centered to student-centered learning paradigm (Hadi & Irfan, 2024). Because the RME approach requires students to actively construct their own knowledge by using the real world to develop mathematical ideas and concepts (Ananda, 2018).

According to Freudenthal in research Anggraini & Fuzan (2024), RME is a student-centered learning approach and learning starts from contextual problems. Mulbar & Zaki (2018) also argue that RME is an innovative learning approach that emphasizes mathematics as a human activity that must be linked to real life. According to Hidayat in the research Ramadhanti & Marlina (2019) that RME has five characteristics, namely the use of the contextual problem, use of models, bridging by vertical instruments, student contribution, interactivity, intertwining. Based on these characteristics, it can be seen, how students communicate their ideas to answer contextual problems given by the teacher, how students contribute in producing and constructing their thoughts and reflecting on the parts they consider important, how students actively participate in discussions, negotiations and how students are responsible for obtaining their own answers (Asikin & Junaedi, 2013). Therefore, in this study, the researcher used the RME approach. In using the RME approach, the researcher needs to design a Hypothetical Learning Trajectory (HLT) first, because HLT acts as a guide for researchers to help students learn in a more structured and directed manner.

HLT is an assumption of learning trajectories based on anticipation of student learning that will be achieved in learning activities, then becomes the basis for making designs for teachers (Haqq et al., 2018). The term HLT was first introduced by Simon in the research of Hendrik et al (2020), HLT consists of three main components, namely learning objectives, learning activities, and assumptions of the learning process. These assumptions include predictions about how students' thinking and understanding will develop during learning activities. Learning objectives refer to achieving an understanding of mathematical concepts, while learning activities include a series of tasks designed to explore students' ways of thinking. then, hypotheses about students' ways of thinking refer to their thinking processes in understanding the concepts taught (Surya, 2018). In addition, HLT is used by researchers to design learning that is in line with students' mindsets in the classroom, adjusted to the characteristics of each student (Rezky, 2019). So it can be concluded that HLT is an assumption of learning trajectories that include learning objectives, learning activities and student response hypotheses to help teachers design learning according to students' needs and characteristics.

Research related to HLT has been conducted previously by previous researchers with various material topics. In the research of Lesmana et al (2024) with the results, the researcher succeeded in designing HLT with the context of rajapolah crafts on the material of measuring the volume of geometric shapes. Similarly, Rofiqoh et al (2023) showed that the designed HLT was feasible, practical, and effective for use in geometry material with the RME approach (Aklimawati et al., 2022). Therefore, HLT needs to be developed to plan learning activities to be more effective. Research conducted showed that in the application of the designed HLT, students were able to understand the material on addition operations using the RME approach assisted by the cultural context in the form of traditional apem cake food. The research conducted by Juniarti et al (2022) showed that HLT with the context of rabana has an important role in supporting students' understanding of the concept of circles. In this study, the researcher used a different context from previous studies, namely tampah. This context is used because the circular tampah can be connected by determining the central angle and the circumference angle.

Based on the literature that has been presented, there has been no research that specifically examines the design of HLT for circle material, especially in determining the relationship between the central angle and the circumference of a circle with the RME approach using the tampah context. Therefore, this research was conducted so that students could find the relationship between the central angle and the circumference of a circle. By utilizing the tampah context, the purpose of this research is to design HLT in circle learning activities, especially the material on the relationship between the central angle and the circumference of a circle with the RME approach.

Method

This research uses the design research method proposed by Gravemeijer & Cobb in the research (Fauzan & Sari, 2017). Design research involves a systematic approach to learning, involving the process of designing, developing, and evaluating various educational interventions, such as learning programs, learning environments, teaching materials, learning products, and learning systems (Rahayu et al., 2024). This method also plays a role in developing HLT to strengthen students' understanding of the relationship between the central angle and the circumference of a circle. This study was conducted at MAN 2 Sungai Penuh, involving 16 grade XI students who were grouped into five groups. Data were obtained using observation, documentation, and interview techniques, including the results of student activity sheets. This design research involves three stages, namely the initial planning stage, experiments, and retrospective analysis (Aisy et al., 2024).

Initial Planning

In the initial planning phase, three things are. First, analysis of literature needs in the form of material and curriculum analysis, subject and school environment analysis, exploratory interviews with teachers, and RME. Second, compiling the HLT which is then explained and further detailed in the experimental design stage (Bakker, 2018). Third, the HLT will be validated by two experts, who will assess its alignment with theoretical principles, practical application, and clarity of learning activities. Their feedback will be used to refine the design so that it can be adjusted appropriately during the experimental phase.

Experimental design

The experimental design stage involves two stages, namely pilot experiments and learning experiments (Bakker, 2018). In the pilot experiment, the previously prepared HLT was applied to small groups of three grade XI students at random. This stage aims to observe and analyze student strategies and mastery during the learning process. Based on the evaluation results from the first group, the HLT was revised and refined. The improved HLT was then reapplied to the second group. In the experimental learning stage, testing was conducted in a larger class with 16 students. Data were obtained through classroom observation and analysis of student activity sheets.

Retrospective analysis

Retrospective analysis was conducted after the experimental design. This analysis was in the form of evaluating whether the planned HLT was running as expected (Fauzan & Sari, 2017), by comparing the assumptions in the HLT designed in the initial planning with the data obtained during the study. This HLT was then used as a guideline in analyzing the data, so that it can be understood how students understand the relationship between the circumference angle and the center angle of the circle. The results of this analysis describe students' assumptions in understanding the relationship, using the context of a tampah.

Results and Discussion

Initial planning

In the initial planning stage the researcher carried out an analysis of the curriculum, subject and school environment. As shown in table 1.

Table 1. *Results of Curriculum Analysis, Subject Analysis and School Environment*

Curriculum Analysis	Subject Analysis and School Environment
At the end of phase F, students understand that the central angle is formed by two radii of a circle and the angle of circumference is the angle formed by the tangent and the radius of the circle, know that the size of the angle of circumference is half of the size of the central angle and the size of the central angle is twice the size of the angle of circumference, are able to calculate the size of the angle of circumference if the size of the central angle is known and are able to calculate the size of the central angle if the size of the angle of circumference is known.	The subjects in this study were students of MAN 2 Sungai Penuh involving 16 students of class XI IPA 2. According to the researcher's findings during the observation some students had difficulty in determining the central angle and the circumference angle and the relationship between the two angles, this was caused by a less varied learning approach. Meanwhile, during the learning process, students had a high curiosity. This was seen when the teacher taught students in biology, where the teacher used aids in the form of human organ statues, it was seen that students were enthusiastic and active during the learning process. Thus, the researcher was interested in using the RME approach by designing HLT so that learning was more structured. Furthermore, during the observation, the researcher also found many woven crafts that had geometric shapes that could be used as a learning context, one of which was a tampah that had a circular shape and was easily found by students in everyday life.

Table 1. Shows the results of the curriculum analysis of the material on the relationship between central angles and circumference angles of a circle in the geometry elements of phase F of high school. Furthermore, during the analysis of the subject and school environment, it was seen that students liked learning that was related to real-world life. This also refers to the school environment, which has many geometric-shaped woven solids, one of which is tampah. Tampah is a type of woven circular shape. According to Oktavia et al (2024), in recent decades, attention to preserving local culture has increased, especially in the context of education, one of which is mathematics learning. Furthermore, Fitri & Prahmana (2020) also argue that one of the contexts that is close to students is the cultural context. This is an opportunity for researchers to apply contextual learning to attract students' enthusiasm and activeness by utilizing the cultural context in the form of tampah. Then, a learning method that is oriented towards technical skills and renewing mathematics education based on solving problems in everyday life. This learning method is RME, which motivates Indonesian mathematics educators to connect learning with everyday life (Hamidah et al., 2024). Educators can create varied learning by developing HLT so that it can be a reference for educators in teaching circle material by utilizing woven crafts especially tampah as a learning context.

Next, design the HLT which includes three main elements, namely, learning objectives, learning activities, and hypotheses about the learning process (Rezky, 2019). The initial HLT that was compiled consisted of 4 activities, namely, sketching a circle, describing the central angle and the circumference angle by applying colored paper, measuring the angles, compiling a table of measurement results, and determining the relationship between the central angle and the circumference angle on the circle. According to Herzamzam (2018), learning activities are useful for developing activity, creativity, critical attitudes, independence, and the ability to communicate with others. Finally, the learning hypothesis that was designed became a guideline in the learning process and was dynamic, so it could be adjusted during the design trial stage. Then the HLT was validated by 2 experts to perfect the initial HLT design so that it could be used at the experimental stage. The validated HLT was suitable for use with revisions, in the form of 2 additional activities to deepen students' knowledge about the relationship between the central angle and the circumference angle. After several revisions and designs, the HLT was suitable for use and tested at the experimental stage.

Experiment

The HLT that has been validated by experts is then tested through small groups and real groups. In the small group trial consisting of 3 students randomly. The results of this stage obtained a discrepancy between the HLT that was compiled and the actual situation. This happened because there was an assumption that arose that was not in the HLT when finding the relationship between the central angle and the circumference angle; namely, students did not make the center point of the circle and did not understand the meaning of determining the relationship between the central angle and the circumference angle of the circle made in the form of a table with the results of the measurements of each angle obtained from previous activities. Based on the results of the trial in small groups, the HLT and student activity sheets that had been made were revised. The results of the HLT revision can be seen in table 2:

Table 1*HLT Revision Results*

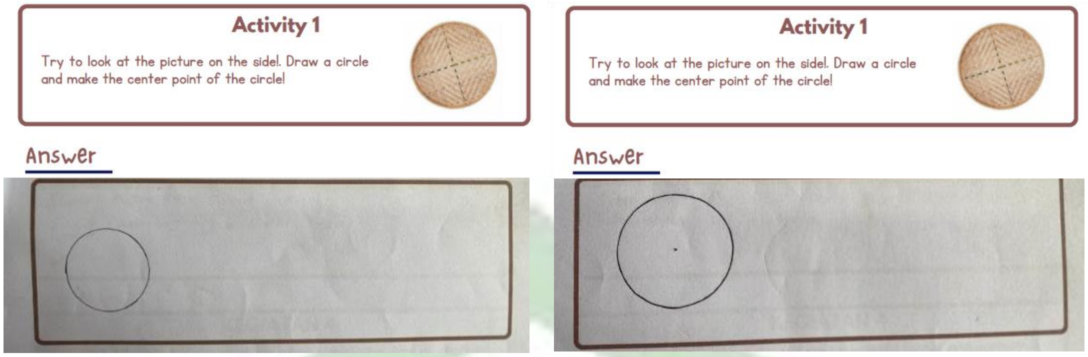
Activity	Objective	Hypothesis
Student notice picture Winnowing and shaping sketch simple.	Knowing the shape of a circle formed by points that are connected to each other and determining the center point.	• Student copy picture tampah complete with point center. • Student copy picture tampah without determine point center
Students draw the circumference angle and central angle formed by 2 origami papers with different colors.	Identifying the angle formed by the connecting lines point center and points on the circle, and determine second corner the.	• Student make picture corner around moreover formerly furthermore corner center, so that seen difference second corner. • Student to form picture corner center moreover formerly furthermore corner around, so that No seen difference second corner.
Students measure the	Get the central angle to	• Student measure big corner center and

size of the circumference angle and the central angle.	be 2 x the circumferential angle, while the circumferential angle is ½ x central angle	corner around. • Measurement results no accurate. Students get size corner around more from ½ size corner center.
Students make a table of the results of measuring the circumference angle and the central angle.	Defines the relationship between the angle of circumference and the central angle of a circle.	• Student make table and get connection corner circumference and angle center circle. • Measurement results no accurate. So that connection corner circumference and angle center circle no obtained.
Students determine the size of the unknown central angle.	Determine the size of the central angle using the formula central angle = 2 x circumference angle.	• Student determine size corner center with formula corner center = 2 x angle around. • Student determine size corner center with ruler bow.
Students determine the size of the unknown circumference angle.	Determine the size of the circumference angle using the formula circumference angle = ½ x central angle.	• Student determine size corner around with formula corner circumference = ½ x angle center. • Student determine size corner around with ruler bow.

Table 2. Shows the results of the HLT revision after small group trials. There are several changes to the hypothesis, one of which is in activity 1, there are students who only draw a circle sketch without determining the center point of the circle so that it does not match the learning objectives, so the researcher added several assumptions to the HLT.

In the experimental stage in the actual class, learning activities were carried out during one meeting in the actual group trial stage in class X1 IPA2 MAN 2 Sungai Penuh against 16 students who were divided into five groups. students work together in groups of 3-4 people. At this stage, the researcher used the previously revised HLT and student activity sheets. Teaching and learning activities were carried out using the RME approach by providing student activity sheets, which were worked on in groups. Through this, students discuss with each other and can contribute to each other during the student activity sheets completion process. The emergence of student activity sheets or practice questions has a positive impact on encouraging students to think, communicate, and work together during the learning process (Yono et al., 2019).

Activity 1: Drawing a simple sketch of a tampah. At the informal stage, students begin to be introduced to the concept of a circle with a tampah as the learning context. The teacher introduces the shape of the tampah to students with the hope that the tampah has a similar understanding to achieve learning objectives, namely that students are expected to be able to sketch a tray and determine the center point of the sketch. The use of real objects such as a tampah in learning reflects the RME approach, namely utilizing contextual problems. Figure 1 shows the results of activity 1.

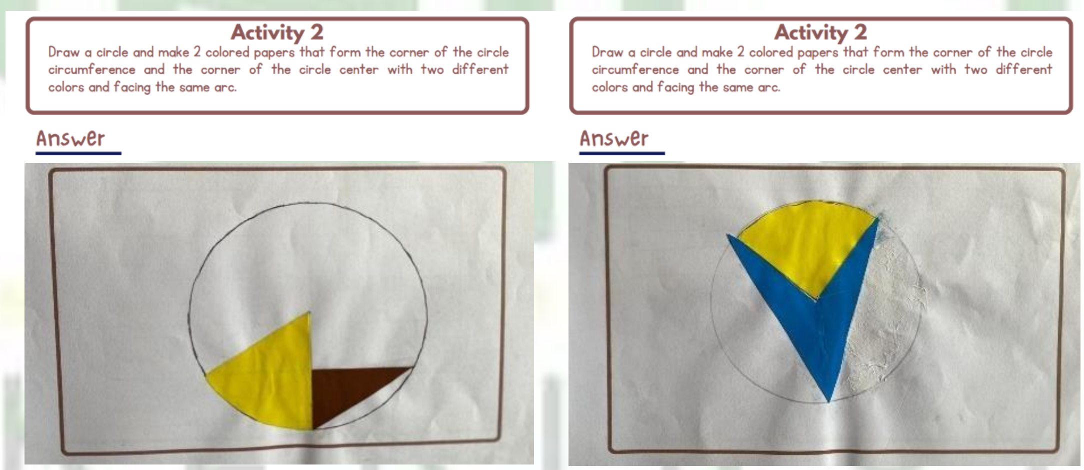


(a) ***(b)***

***Figure 1**. Tampah Sketch*

From Figure 1(a) and 1(b), there are differences between the two. In Figure 1(a) the student has not determined the center point because he forgot, this is due to the lack of student attention to the instructions given in student activity sheets. Figure 1(b) shows that the student's results are correct and meet the initial assumptions designed in HLT.

Activity 2: Students are asked to draw a circle with a free size and cut two colored papers by producing paper pieces that form the circumference angle and the center angle of the circle. Furthermore, there are three steps that must be taken to recreate the shape of the tampah, namely (1) drawing a circle with a larger size than the previous circle, (2) setting the angle at the center of the circle as angle α, (3) ensuring that angle α faces the same arc as the circumference angle of the circle. When working on this activity, students are confused about attaching the paper pieces of the center angle and the circumference angle. Then the researcher guides the students with instructions for students to try attaching the paper before being given adhesive first, so that students find the answer. Figure 2 shows the results of activity 2.

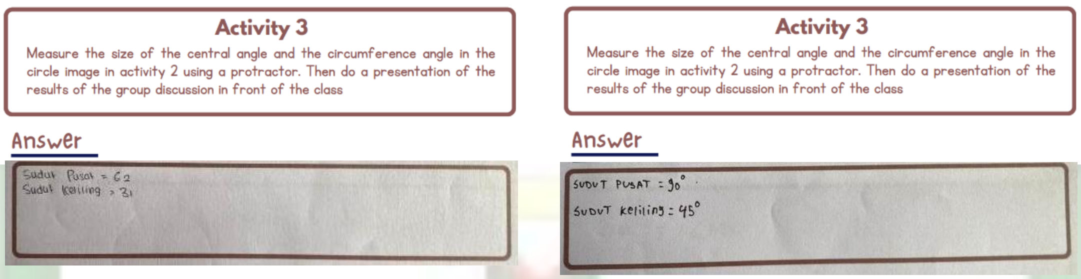


(a) ***(b)***

***Figure 2**. Central Angle and Circumferential Angle Formed*

There are two ways that students use to draw the circumference and center angles of a circle. In Figure 2(a), students draw the circumference and center angles correctly because both face the same arc, namely the arc at the bottom of the circle. Meanwhile, in Figure 2(b), students also draw the circumference and center angles facing the same arc, but the arc is at the top of the circle. The results of this student's work are in line with the predictions formulated by the researcher in HLT.

Activity 3: Measuring the size of the circumference and center angles. In this activity, students are asked to measure the size of the circumference and center angles based on the drawing that has been made in Activity 2 using a protractor. Furthermore, the measurement results obtained are presented by all groups. In the process, students discuss with group members about the size of the angle formed. If the size of the circumference turns out to be twice as small as the center angle, then the drawing made is considered appropriate. Figure 3 shows the results of Activity 3.

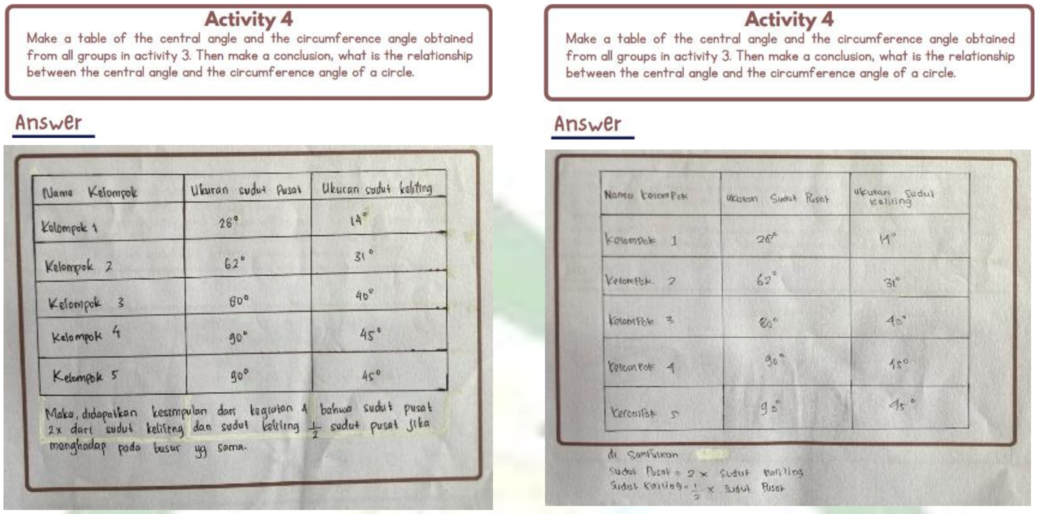


(a) ***(b)***

Figure 3*. Measuring Central Angles and Perimeter Angles*

Figure 3 shows that students measure the central angle first, then continue with the circumference angle according to the instructions in the student activity sheets. In addition, there are some students who are still confused about how to use a protractor. Then the researcher guides students by explaining how to use a protractor correctly, so that students find the answer accurately, this is in line with the initial assumptions made by the researcher in the HLT.

Activity 4: Make a table of the size of the circumference angle and the size of the center angle of a circle and conclude the relationship between the circumference angle and the center angle of a circle. In this activity, the teacher instructs students to compile a table based on the measurement results from each group that have been presented in Activity 3. When compiling the table, students are confused about what table format to use. The researcher guides students by giving instructions for students to determine what columns are needed according to the instructions on the activity sheet. Next, students discuss in groups to compile a table and formulate conclusions based on the results of the four activities. Next, instructions on the model where they compare data from all groups and determine the relationships found (model for). Each group completes the table correctly. Figure 4 shows the results of Activity 4.

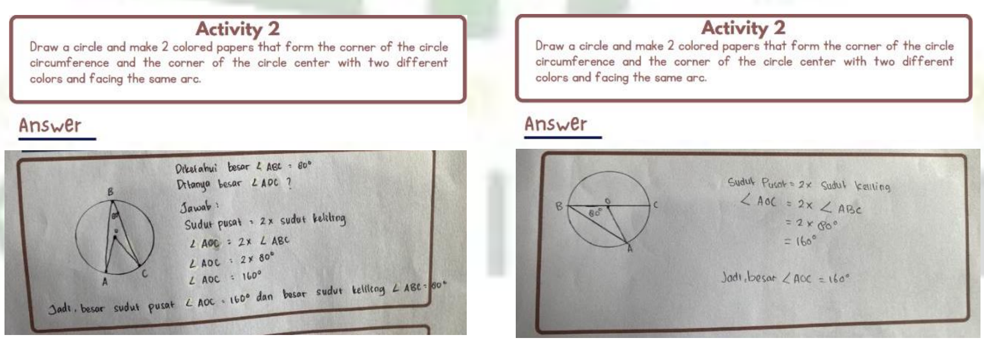


(a) **(b)**

Figure 4*. Table of Central Angle and Circumference Angle Measurements and Their Relationship*

Figure 4 shows that students can determine the relationship between the central angle and the circumference angle correctly. Activity 4 shows that the third principle of RME is fulfilled, namely the level of understanding, where students start with an informal approach using their methods (model of), then move on to the model for and finally reach a formal understanding called self-developed models (Fauzana, 2022).

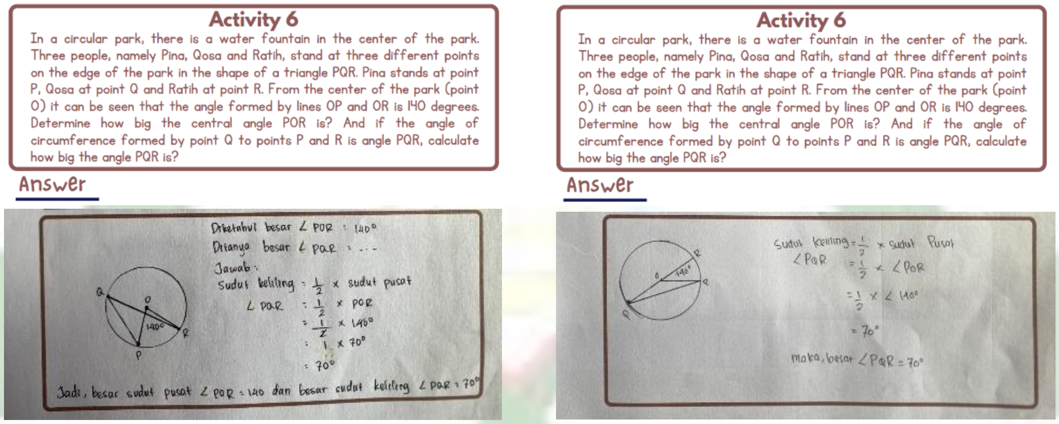
Activity 5: Determining the size of the central angle. In this activity, the researcher guides students to ensure the size of the unknown angle and compare it with the size of the known circumference angle, according to the instructions on the student activity sheet. Students discuss in groups about the size of the central angle of a circle. In this activity, the researcher asks the question how to determine the size of the central angle?, students can answer the central angle, which is 2 times the circumference angle. All groups successfully determined the size of the central angle correctly using the formula that had been learned in the previous activity. Figure 5 shows the results of activity 5.



(a) **(b)**

Figure 5*. Application of the Central Angle Concept*

Activ ... er directs students to calculate the size of the unknown circumference angle and compare it with the size of the known central angle, in line with the instructions in the student activity sheets. Students discuss in groups to determine the size of the circumference angle on the circle. Then the researcher asks again what should be done next? Students can answer that what needs to be done is to find the size of the circumference angle with the formula circumference angle = 1/2 × central angle. By applying this formula, all groups succeeded in determining the size of the circumference angle correctly. Figure 6 shows the results of student work in activity 6.



(a) ***(b)***

***Figure 6**. Application of the Concept of Circumference Angle*

During learning in activities 1 to 6, there is interactivity. Interactions take the form of communication, cooperation, explanation, and evaluation (Syahri, 2017), between teachers and students and between students. The dialogue that emerged in the study is a form of interaction between teachers and students. Researchers guide all groups during class discussions. Guidance is in the form of providing direction through structured commands or questions in activity sheets and teacher responses to student problems. Researchers guide students both in groups and individually and researchers provide responses according to those listed in the research results section.

Retrospective Analysis

Retrospective analysis has a significant contribution to implementing HLT using the RME approach, especially during the experimental stage. At the small group trial stage consisting of 3 students randomly, there was a discrepancy between the HLT that was prepared and the actual situation. This can be seen from several allegations that occurred during the small group trial, which were not found in the initial HLT that was prepared. In addition, students still need incentive guidance from the teacher, because no students want to come to the front of the class to present the results of their student activity sheets work. Therefore, other findings from this analysis indicate the need for teachers to provide different approaches for each group, considering that the abilities of each group are not entirely equal.

In the classroom trial stage, some groups were able to immediately solve contextual problems because they had members who understood the material, while other groups needed additional guidance from the teacher. During the classroom trial, it was seen that students had more curiosity and were more active during the learning process. Students who were still confused about working on the student activity sheets dared to ask several questions. In addition, the direction in the form of bait questions given by the teacher proved to greatly influence the smoothness of the discussion. Overall, the implementation of HLT in the classroom took place according to the initial predictions and hypotheses because the obstacles that might arise had been minimized and anticipated based on the results of the trial in small groups. Meanwhile, in the large class trial stage, most students were more active and creative in completing all the activities in the student activity sheets.

The results of the application of this research realize the contribution of a series of activities designed to help grade IX students understand the material. By implementing the RME approach through the tampah context, students need to follow all the activities and steps given to make it easier for students to understand the learning. In learning carried out using the RME approach, there are 4 steps, namely students understand contextual problems, explain contextual problems, solve contextual problems, and compare and discuss answers (Anugraini & Purnomo, 2022). According to Treffers in the research Van den Heuvel-Panhuizen & Drijvers (2020) the RME approach has 6 main principles, namely: The activity principle, The reality principle, The level principle, The intertwinement principle, The interactivity principle and, The guidance principle. In learning using the RME approach, an HLT is compiled. HLT consists of three interrelated components, namely meaningful learning objectives, learning activities in the form of a series of tasks to achieve these objectives, and hypotheses about how students learn and think.

HLT with the RME approach is often used in teaching mathematics lessons to students through contextual problems, such as the concept of Sets (Sukirwan et al., 2022), Area of a Circle (Budiyono et al., 2019), Pythagorean Theorem (Wandanu et al., 2020), Probability (Anggraini et al., 2022), and others. HLT with the RME approach that was tested in this study was on the Circle material, especially in determining the relationship between the central angle and the circumference of a circle with a tampah as a context. tampah is a traditional woven material that is circular and easily found in society. Through tampah, students can find the shape of a circle, the central angle, and the circumference.

The RME approach has been proven to help students determine the relationship between the central angle and the circumference of a circle. RME presents learning with a real context through direct experience, in addition, learning activities emphasize the application of reality that can be imagined by students through the presentation of certain contexts (Ramadhan et al., 2024). This is in line with research conducted by Dwiputri et al (2023) showing that the application of RME can increase the average value of students' understanding, with better learning outcomes after several meetings. The results of this study also show that the RME approach developed in this study meets valid criteria. One of the challenges in this study is the limited time when working on student activity sheets.

Conclusion

This HLT can make it easier for students to understand the material about the relationship between the central angle and the circumference of a circle through six activity steps. The results of the study indicate that the RME approach with the Tampah context is useful as a tool used to design HLT for student understanding. The results of this study support several previous studies that state that learning activities related to daily activities can be a starting point in learning mathematics. Therefore, the HLT design with the Tampah context can be an alternative activity in learning circles, especially the relationship between the central angle and the circumference of a circle for grade XI students.

Based on the results of this study, the researcher suggests that further research can use other contexts to find the relationship between the central angle and the circumference of a circle with the RME approach. In addition, the results of this study can be a reference for further researchers to develop similar learning designs with different topics.

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