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The Learning Trajectory of Set Concept Using Realistic Mathematics Education (RME)

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Abstract

Learning trajectory of set is a learning path to get concept of set. However, several teachers did not combine methods, approaches, and ideas in their practical deliveries. This situation becomes a concern for teachers to handle since it will affect the rule without reason so that the accepted concept will not last long in students' memory. This study aim to describe the learning trajectory using RME models to construct the concept of set. Hypothetical learning trajectory (HLT) was designed using a qualitative method with the realistic mathematics education (RME) of Gravemeijer model as the activity stage begin from preparing for the experiment, pilot experiment, teaching experiment and retrospective analysis. The designed HLT consisted of an objective, activity, and conjecture. This study achieved an understanding of the set concept with applying RME design. By providing examples of contextual mathematics that take place in the learning environment, these outcomes were achieved. Then using media like set cards to model mathematics so that students can advance their own knowledge to the level of formal mathematics. Therefore, the RME-based HLT design can be a solution to obtain the concept of set, primarily in domain definition and set notation to produce a learning trajectory.

Keywords: Learning Trajectory, Realistic Mathematics Education, Set

Abstrak

Lintasan belajar pada materi himpunan merupakan alur belajar yang harus dilalui untuk menggapai sebuah konsep himpunan. Kendati demikian beberapa guru masih belum mekombinasikan metode, pendekatan maupun ide-ide matematis dalam penyampaiannya. Hal ini menjadi kekhawatiran yang perlu ditangani semua calon guru, karena akan berimbas pada sebuah aturan tanpa alasan sehingga konsep yang diterima tidak akan bertahan lama di benak siswa. Tujuan penelitian ini untuk menggambarkan lintasan belajar berbasis proyek model RME untuk membangun pemahaman konsep himpunan. Metode yang digunakan dalam merancang HLT adalah metode kualitatif jenis penelitian desain berbasis realistic mathematics education (RME) model Gravemeijer yang dimulai dari aktivitas *preparing for the experiment*, *pilot experiment*, *teaching experiment*, dan *restropective analysis*. HLT yang dirancang mencakup sebuah tujuan, aktivitas dan konjektur. Hasil penelitian ini adalah tercapainya pemahaman konsep himpunan dengan menerapkan desain RME. Hasil tersebut diperoleh melalui pemberian contoh matematika kontekstual yang terjadi di lingkungan belajar. kemudian memodelkan matematika dengan berbantuan media seperti kartu himpunan sehingga siswa membangun sendiri pengetahuannya ke tahapan matematika formal. Untuk itu, learning trajectory berbasis RME dapat menjadi salah satu solusi dalam mencapai konsep himpunan khususnya pada domain definisi dan notasi himpunan hingga menghasilkan sebuah learning trajectory.

Kata kunci: *Learning Trajectory*, *Realistic Mathematics Education*, Himpunan,

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INTRODUCTION

Mathematics requires several essential elements to build a meaningful concept (Marasabessy & Hasanah, 2021). The assumed concept can develop students' mindset on responding to various

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surrounding objects. However, the occurring issues are different with the proposed theories. This phenomenon is due to the implementation of mathematics at school. It is said that mathematics learning has not yet combined mathematical approaches, methods, and ideas as alternatives to facilitate students building their knowledge (Amirante et al., 2022; Posamentier & Smith, 2020).

In response to the preceding situation, Freudenthal (2006) states that students need an appropriate approach that can build a mathematical concept to obtain understanding and solution to phenomena they experience directly-related to their previous knowledge. This idea refers to a statement that “mathematics is really close to everyday life” (Gazali, 2016; Puspaningtyas & Ulfa, 2020), taking a place at school as a formal education. Therefore, mathematics is a compulsory subject from elementary school to the next levels (Astuti & Wijaya, 2020; Risdiyanti & Prahmana, 2021).

The precedingly mentioned trajectory of formal education is in line with a theory called realistic mathematics education (RME). RME emphasizes on a context to build mathematical mindset. RME context used in this study was objects that students frequently found in daily life, such as those at school and home. This mindset is due to an idea that the basis of mathematics is human activities. In its application, RME is supported by principles (guided reinvention. progressive mathematization, didactical phenomenology, and emergent models) and characteristics (contextual issues, contribution, models and interaction in learning process, and intertwine of mathematical concepts) to strive for more meaningful learning (Arsoetar & Sugiman, 2019; Purwati, 2020; Sirait & Azis, 2017; Tunjungsari & Tasyanti, 2017).

Mathematics is also intertwined with reality. Its learning corresponds to students’ experiences. Typically, the obstacles experienced include students erroneously reading the questions, lack of understanding of symbols, place values, calculations, and use of inappropriate processes (Schoenfeld, 1988). Anggraeni and Kadarisma (2020) argue that set is one of the materials mistakenly accepted. The error is in the forms of question identification and its completion. Set is a group of objects that can be defined and distinguished. According to Dwidarti et al. (2019), set possesses a quite high level of difficulty, primarily in the process of representation of narrative-based question or set formation notation. The writing of set formation notation is commonly hard to understand as the students cannot read the symbol (Andriani, 2019).

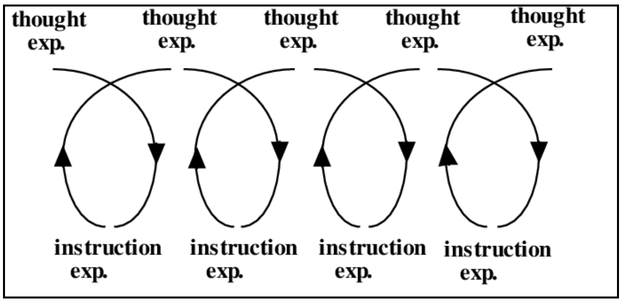
Based on interviews at SMPIT Al-Fatih, a student had difficulty distinguishing objects that are sets and not sets into the notation of forming sets. The difficulty is assumed due to the online learning that does not involve context and just directly gives formulas. The online learning leads to less motivated students in mathematics learning (Amelia et al., 2020; Chan & Wilson, 2020; Kim et al., 2015). Students found it difficult to interpret Venn diagrams and set formation notation into mathematical models so that their concepts did not last long (Maxwell et al., 2017). This is supported by the results of interviews on teachers, triggering the researchers to reconsider designing an RME-based learning trajectory to help students reason well.

Considering the urgency of the learning trajectory, it is important to use the development trajectory on thinking levels as a tool to meet the expected knowledge domain (Clements et al., 2012; Surya, 2018). Chen (2016) proposed primary components in designing the learning trajectory, namely 1) learning objectives, 2) learning activities, and 3) hypothetical learning process. Hence, LT design can assist teachers to reveal the development of students' understanding on given materials.

This recent study has relevance with several previous studies. Clements et al. (2012) aims to describe things as frequently done by small children to make a geometric shape. It shows good results for developing abilities in making two-dimensional shapes. Meanwhile, Kusrini & Rizkianto (2018) state that designing learning trajectories can help students understand concepts. It improves critical thinking skills (Astuti & Wijaya, 2020), creative thinking skills (Hedayani, 2018), mathematical communication skills (Nuraida & Amam, 2019), and mathematical reasoning abilities (Sarvita & Syarifuddin, 2020). Departing from the elaborated background, this study aims to design a learning trajectory based on realistic mathematics education on set material focused on the definition and way of presenting sets either by mentioning sentences, members, or set notation.

METHODS

Hypothetical learning trajectory (HLT) was designed using a qualitative method with the RME approach. The characteristics can be seen in Figure 1.



` Sources: (Gravemeijer & Cobb, 2006)

Figure 1. Design research cycle

The cycle focused on instructional activity test in constructing learning trajectory based on process perspective. Teachers anticipated various things during the learning process. At the end, HLT would be fixed or improved if any discrepancy was found in learning activities. Participants in this pilot experiment were six class VII students.

The researchers implemented a model by Gravemeijer & Cobb (2006) as a basis consisting of three stages. First, in preparing for the experiment, interviews on difficulties experienced by students on set were carried out. Students stated they faced difficulties on understanding set notation formulation and changing it into venn diagrams. Therefore, the appropriate material for set learning is introduction to various examples in reality and HLT design. Second, the selected experiment design was HLT try out on volunteers that would be used in the teaching experiment. Third, the retrospective analysis was done to analyze all compiled data for improving HLT.

Data collection techniques applied were interviews and documentation. The instruments used consisted of various learning activities and conjectures with learning objectives-validated by mathematics teachers and lecturers. In addition, data analysis techniques were qualitative. The researchers observed and examined the results of data collection from the tasks, interviews with students, and documentation of the learning process.

RESULTS AND DISCUSSION

The mini-research carried out by the researchers took four meetings as described in the Figure 2.

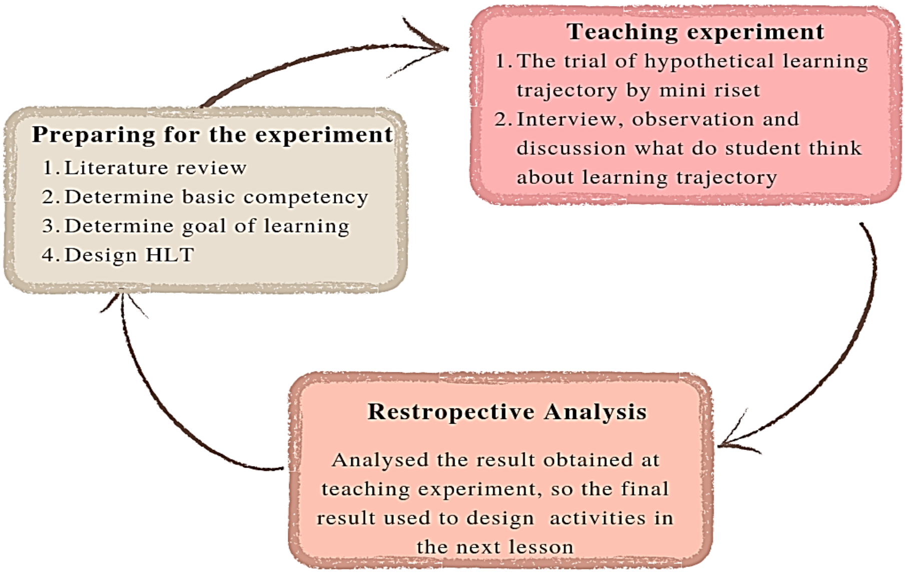


Figure 2. Design research cycle

Preparing for the Experiment

The results of HLT demonstrate learning objectives in which students could distinguish sets and not-sets, reveal the concept of set definition, present set with the sentence and member(s), show set with set formulation notation, and understand various ways to present set. The researchers then prepared learning materials for HLT. HLT was designed as it is to facilitate students finding the concept of set. The assumptions of students' learning process were 1) students could mention and differentiate sets and not-sets, 2) students could define sets they understood, 3) students could mention set members, 4) students could determine the total of set members, and 5) students mistakenly determine set members.

The first activity was related to contextual mathematics. The given context was intertwined to the reality at school and home. Students were given assignment 1 related to the definition of a set where the task aimed to assist them in identifying the concept of a set by looking for various examples around their homes. After that, students wrote down examples they obtained, and the teachers enquired whether the objects were appropriate based on the types, characteristics, and specifications. If it was not appropriate, the teachers then gave suitable examples see Figure 3.

Figure 3. The example of activity 1

This activity is supported by a theory on calculus material proposed in Da (2022) and Gravemeijer (2020). Calculus material begins from the context of real phenomena as stated in the principles of didactical phenomenology and RME characteristics. Under this principle, activity 1 began with identifying objects based on didactic phenomena that students experienced directly. Therefore, students can distinguish sets and not-sets. In the final stage, the teachers asked them to define the meaning of the set according to their understanding. However, the constraints occurred in the pilot experiment process; students were unable to provide examples of a collection of objects based on their specific characteristics. Hence, researchers need to conduct interviews to confirm their understanding of the compiled objects.

Researcher: Of your compiled objects, is there any to add?

Student 1 : Yes, it is. All can be added. The first group includes electronic stuff such as laptops and computers.

Researcher: After given other examples on a group of plant objects in the forms of roses, orchids, aglonema, and monstera, are your examples in line with characteristics and specific?

Student 1 : Some of my examples are already specific. Some are not, such as a group of transportation.

Researcher: Why do you think they are not yet matching?

Student 1 : Because I can classify them more specifically into a group of ground or public transportation.

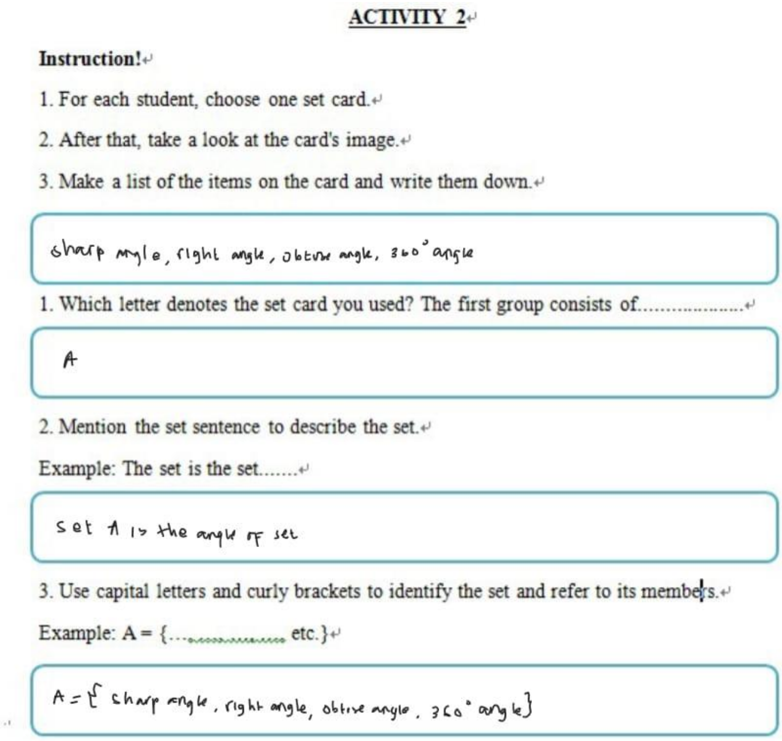
Researcher: Then, after you found out a number of objects around your home, can you define set?

Student 1 : In my opinion, set is a group of similar and specific objects.

Based on the interview with student 1, it is known that the student could understand and mention other objects on the given examples. However, the student could not mention the objects based on the characteristics more specifically. The researchers led him to define set with his own understanding.

Teaching Experiment

At this stage, learning objectives went in line with pilot experiment objectives. The results of HLT in the second activity (mathematics model) show that the students could distinguish sets and not-sets. However, their knowledge should be extended with other examples so that the objects are not only those around them. During the process, teachers gave an assignment containing activity 2 (see Figure 4) with set cards as the medium. The given cards were like uno. They contained groups of objects and numbers related to mathematics in daily life such as cartoons, angles, flat shapes, public transportation, odd numbers, integers, and natural numbers. On the other side, various capital letters were attached to each card to symbolize the set. The cards were handed out to introduce the sets. It also facilitated students to present the sets by directly contributing to the process by mentioning the sentences and members. The characteristic of RME in this activity is student contribution (Hery et al., 2018). It can be seen in Figure 4.



ACTIVITY 2

Instruction!

1. For each student, choose one set card.
2. After that, take a look at the card's image.
3. Make a list of the items on the card and write them down.

sharp angle, right angle, obtuse angle, 360° angle

1. Which letter denotes the set card you used? The first group consists of..................

A

2. Mention the set sentence to describe the set.

Example: The set is the set.......

set A is the angle of set

3. Use capital letters and curly brackets to identify the set and refer to its members.

Example: A = {................ etc.}

A = {sharp angle, right angle, obtive angle, 360° angle}

Figure 4. Example of answering student in activity 2

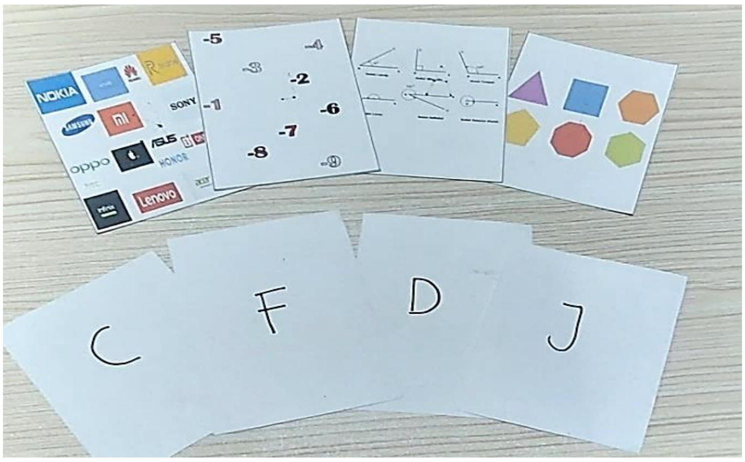


Figure 5. Card of set

Based on Figure 5, students could reveal sets by mentioning the sentences and members on the cards. Students followed the steps by using capital letters to represent sets and using curly brackets to name the members. After that, students selected a card related to the set of numbers and identified it. The teachers conducted interviews to confirm students' understanding.

Researcher: What letter does represent objects on set cards that you chose?

Student 2 : Letter A

Researcher: How do you state that set with the sentence set?

Student 2 : Set A is an angle set.

Researcher: What are the members of the angle? State with set members!

Student 2 : A = { acute angle, right angle, obtuse angle, straight angle, reflection angle, full rotation angle}

Researcher: What set of cards did you get?

Student 2 : A set of odd numbers

Researcher: Can you mention another example and state it with a set sentence and name its members?

Student 2 : The set X is the set of colors. X = {red, orange, yellow, green, blue, purple, gray, pink, brown}

Based on the interview with student 2, it is revealed that the student could present the set correctly through two ways, namely set sentence and set members. The researchers then asked students to take other examples and express them in sentences and members of sets. Activity 2 contains the principle of guided reinvention on the concept of set (Simanulang, 2014). The reinvention process is guided by the researcher linking the first activity so that students can present the set based on the sentence. They can also mention the members of each set.

Restropective Analysis

Going through four levels of contextual mathematics processes and providing examples related to everyday life at school and at home generate learning trajectories. In addition, students are given back assignments when they are able to provide examples, just like when set cards are used to teach experiments. Students can use their knowledge of situational mathematics to indirectly model more formal mathematics at this level. Students are also able to present sets using set notation, members, and sentences at the level of conceptual building in mathematics. So that students can define the idea of sets and the notation for forming sets at the final level, also known as the level of formal mathematics.

At this stage, the researchers analyzed previously compiled data. Students here had been able to state sets with sentences and mentioned the members in an appropriate procedure. They were also given an assignment related to contextual issues at market. Teachers reminded them of previous materials on mentioning set members. After that, students stated them in a set formulation notation by following the examples consisting of symbols. That was the way to read the notation. At the end, students were required to complete empty parts in the table by handing them out an instruction to state the set.

The results indicate that students can express sets by mentioning the members and notation for forming sets. They can also present sets in three ways, namely members, sentences, and notations. However, some students still could not classify the types of numbers such as prime numbers and integers. They stated that the types of sentences were integers, whole numbers, and natural numbers. Only one student could classify it as a prime number. This situation indicated that students were still unable to distinguish the types of mathematical numbers. Therefore, the teacher conducted interviews to confirm students' understanding, especially on the types of numbers in sets and how to express sets with the notation of their formation.

Researcher : Can you read set notation that you presented in assignment 3?

Student 3 : Yes, I can. F = {z} so that z is a member of the kitchen.

Researcher : What kind of difficulties did you face in activity 3?

Student 3 : I am still mistaken on the sets of whole, integer, odd and prime numbers.

Researcher : After you know the difference between them, so which set that number 4 in the fourth table belongs to?

Student 3 : The set of prime numbers.

Based on the interview with student 3, it is concluded that the student could present the set with set formulation notation. However, he still made a mistake in presenting sets of numbers and needed a longer time to understand the meaning of set formulation notation. Activity 3 contains the principle of emergent models as used in Gravemeijer (2020) and Meidiana et al. (2021). It also shows the characteristics with model/ table/ chart where students can relate activity 2. The flow of students' thinking in presenting sets with sentences and mentioning members undergoes a horizontal mathematization process (Najwa et al., 2019) by providing set notation which involves various symbols such as curly brackets and variables. The results of compiled data can be seen in the following iceberg illustration.

Figure 6. Iceberg design set material

Figure 6 shows an iceberg describing the flow of students' learning on set material so as to achieve the objective, namely understanding the definition of set and set notation. This result is supported by studies by Astuti & Wijaya (2020) and Risdiyanti & Prahmana (2021) that examined the trajectory of learning in set material. Based on the results, the method can be a solution to overcome students' difficulties in understanding the concept of sets. This flow relates to the stages of the RME approach which has a starting point on contextual problems. It is able to transform the situation model into a mathematical model. This situation is followed by building knowledge of mathematical models by presenting them in a table to facilitate students to distinguish set presentations with sentences and members.

This way, students can provide sets with a more formal notation. At the final stage of formal mathematics, students can find a set definition concept and set notation. The application of an RME-based learning trajectory can construct students' understanding and develop their mindset to solve problems in various materials such as circle (Indriani & Julie, 2017), statistics (Fauzan et al., 2018), and arithmetic (Fauzan & Diana, 2020). However, learning trajectory is beneficial for improving problem solving abilities (Towe & Julie, 2020) and mathematical communication (Nuraida & Amam, 2019). This study has a limitation in terms of participants. It was quite difficult to look for students at the pilot experiment stage since the research was carried out during the school off hours.

CONCLUSION

The implementation of contextual mathematics activity is proposed for students to understand the concept of set. The designed learning trajectory contains objectives of set learning, activities in gaining the concept of set, and set notations. The used RME design starts from various didactic phenomena experienced by students at school to the stage of formal mathematics. This research can develop students' mental activity to think mathematically. It can be seen in the revised HLT which facilitates a learning trajectory. Based on the conclusion, some suggestions are 1) RME-based learning trajectory can assist students to understand other mathematical concepts and 2) the development of LT can be modified with other mathematical models to facilitate the understanding of set.

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