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The Development of Students' Learning Material on Arithmatic Sequence Using PMRI Approach

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ABSTRACT
The aim of the learning process in this study was to help students find concepts on arithmetic sequence materials using the approach of Pendidikan Matematika Realistik Indonesia (PMRI) as well as produce a path of arithmetic sequence learning using PMRI approach. This research method was design research which was an appropriate way to answer research questions and achieve research objectives. The research procedure used was preliminary design, teaching experiment and retrospective analysis. This research was conducted on the students of class X in one private high school . The main data analysis techniques were restrospective analysis in collaboration with counselors to improve the validity of the research results. The results showed that the use of PMRI approach provides an important role in learning arithmetic sequence and increasing student's motivation to learn. Context used and interesting learning guided students to explore and use strategies to solve problems related to arithmetic sequences in everyday life. Then learning trajectory of a HLT (Hypothetical Learning Trajectory) was generated. The learning path of students in arithmetic learning progresses from the informal to the formal stage so as to enhance students' understanding of arithmetic learning.

Keywords: *Design Research, Hypothetical Learning Trajectory, Learning Trajectory, PMRI Approach*

1. INTRODUCTION

Mathematics is study of a science with a hierarchical object, a certain mathematical topic will be a prerequisite material for the next topic. To learn a new mathematical topic, student learning experiences will influence the learning process. A certain material will be mastered by students well when they are able to master the prerequisite material well [1]. With the characteristics of such students, the teacher can learn a material if the teacher has a picture of the possible trajectories or paths that students travel to achieve the specified learning goals.

The success of learning cannot be separated from the ability of a teacher in designing a learning plan before teaching. Learning planning should be made in writing. It is done by teachers can assess themselves during the learning process. One tangible form of learning planning is the Learning Implementation Plan (LIP). Based on experience, the reality in the field shows that the learning design that has been prepared is often not in accordance with the implementation due to students' responses that appear unexpectedly. Learning implementation plan will be implemented well if it is equipped with predictions about how the possibility of student learning process. The prediction in question is related to how students' thinking skills and understanding will develop in learning activities designed by the teacher. Predictions about developing student responses are contained in a learning design called the Hypothetical Learning Trajectory (HLT). Simon [2] revealed that HLT consists of 3 components, namely learning objectives to define direction and achieve meaningful learning goals, learning activities in the form of a set of tasks, and hypotheses of the learning process in the form of predictions about how students' thinking and understanding develop during learning activities. Whereas learning design is a learning system that functions as a reference in carrying out learning activities [3]. Design means the whole structure, framework and sequence or systematic activity [4]. According to Gagne [5] learning design helped one's learning process, the process itself had immediate and long-term stages. The learning process occurs because of internal and external learning conditions.

Local Instructional Theory (LIT) is a theory of the learning process that describes the trajectory of learning on a particular topic with a set of activities that support it. LIT is a learning trajectory which is the result of development based on thinking to choose a specific learning design, so that the concept of the material to be taught can be understood by students. By knowing the student's learning trajectory, the teacher can find out the appropriate learning trajectory used to assist students in understanding a concept [6].

To create and use of the learning trajectory, it is necessary to have an approach to learning mathematics that is a learning approach adapted from the theory of teaching and learning Realistic Mathematics Education (RME) in the Netherlands namely the Indonesian Realistic Mathematics Education Approach (PMRI), where PMRI is adapted to the conditions in Indonesia [7][11]. Mathematics is taught by using a series of activities for students to understand the concepts of learning and mathematics must be taught with problems that use situations in everyday life [8][12].

Vocational High School (VHS) is a school that prepares students to face the professional work world directly. Mathematical concepts should be well embedded and able to be applied in accordance with their respective majors. However, in reality the application of mathematics cannot be applied because of mathematical concepts that are poorly understood by students. For this reason, a research on how student learning activities could be applied to help students find their own concepts of material taught was needed so that students were able to apply the concepts they had learned in their world of work.

After observed of the learning process that took place at the school precisely at the Catholic Vocational School Santa Familia Tomohon in the 2017-2018 school year, it was found that students had difficulty when studying material in a row and series in class XI. This was due to the lack of understanding of students' concepts in arithmetic row material that should have been learned in class X. Therefore, researchers argued on the need for research on arithmetic row material in class X. For this reason, it was necessary to arrange a learning design that could help students find the concept of material and student learning trajectory. A prediction needed to be made to ensure the method used could be well directed or not. To compile a learning design in accordance with the above problems, researchers were interested in finding out the trajectories of student learning in implanting concepts using the PMRI approach.

2. METHOD

This study used design research method. Gravemeijer and Van Eerde [6] said that design research was a research method aimed to develop LIT in collaboration with researchers and educators to improve the quality of learning. Furthermore, according to Plomp [9] design research included a systematic learning starting from designing, developing and evaluating all interventions related to education, such as programs, learning processes, learning environments, teaching materials, learning products, and learning systems.

Research design was consisted of 3 stages, namely:

1. Preliminary Design

According to Wijaya the main objective of this stage was to develop a sequence of learning activities and design instruments to evaluate the learning process [6].

At this stage the prepared of learning activities was carried out to achieve the learning objectives that have been made at each stage of learning and conjecture (alleged) trajectory of student learning activities in achieving learning objectives. This stage was carried out the preparation of Hypothetical Learning Trajectory (HLT). Conjectures from HLT were formulated for learning objectives, learning activities, and assisting tools for the learning process. This conjecture was used as a guide to anticipate students' strategies and thought processes which emerged and developed during learning activities. Conjectures were dynamic and arranged and revised during the teaching experiment process.

2. Teaching Experiment Phase

At this stage the researchers tried out the learning activities that were designed at the preliminary design stage. This trial aimed to explore and hypothesize students' strategies and thoughts during the actual learning process. This stage was further divided into 2 stages, namely the teaching experiment stage and the pilot stage. Learning trajectories designed at the preliminary design stage were first tested at the teaching experiment stage to adjust the learning trajectory before entering the pilot experiment. During the process, the conjecture could be modified as HLT revision for further activities. At this stage a series of activities designed in the HLT were then conducted by the researcher to observe and analyze the learning activities occurred during the learning process in class. This process aimed to evaluate the conjectures contained in learning activities.

3. Retrospective Analysis Phase

After the design experiment activities in learning, data obtained from learning activities in class were analyzed retrospectively. In general, the purpose of this stage was to develop LIT. Other objectives were to evaluate the success of learning activities that have been implemented, observe student learning progress, and inform the progress of learning activities. The retrospective analysis phase consisted of data analysis, reflection, interpretation of findings, and formulation of

recommendations for future research. Observations at this stage were made on the video recording of learning and analysis of student worksheets (LKS) and then compared to the HLT that has been made. This research was conducted at the Catholic Vocational School Santa Familia Tomohon Class X Catering and Class X Office Administration 1 even semester of the 2017-2018.

Data collection was carried out from various sources such as video recordings, documentation and written data. Video recordings in this study was used to document student learning strategies and activities during the learning process. With the video recording of strategies and learning activities students could be observed carefully. Video recording was carried out during the teaching experiment process. The documentation in this case was in the form of photographs of student learning activities and discussions as evidence related to the conduct of research. Written data in the form of results in student worksheets, field notes, and observation sheets. All this data was collected during the design experiment (teaching experiment). Direct observations made by researchers during the learning process using observation sheets and conducted by 2 observers.

Data obtained were analyzed retrospectively with HLT as a guide. Data analysis was conducted by the researcher and the supervisor to improve the quality of data analysis from this study. Validity in this study referred to HLT as a means to support validity and tractability with the aim that researchers could describe the situation and information in detail. Reliability was done in 2 ways, namely data triangulation and cross interpretation.

3. RESULT AND DISCUSSION

This research was conducted in three stages of design research namely preliminary design, teaching experiment, and retrospective analysis.

3.1 Preliminary Design

At the preliminary design stage, the important thing to observe and study is designing learning activities and developing the alleged learning path of students. Before designing learning activities an analysis of student learning trajectories is carried out on the topic of arithmetic sequences. Furthermore, the alleged student learning trajectory, learning activities and context will be used in learning arithmetic sequences which will become LIT on arithmetic sequence material.

A set of activities for appropriate arithmetic sequence material that designed based on the student's learning path and thought process was hypothesized. The learning pathway for the arithmetic sequence material was divided into 4 activities, completed in 2 meetings. Starting with the activity of arranging the pyramid using a match, discovering the pattern of lines formed in the pyramid arrangement, arranging a pyramid-shaped ice cream cup stack, and finding the pattern of arithmetic sequences in the pyramid arrangement. All activities were tested first on a pilot experiment. The results of the pilot experiment were compared with the HLT that was made, then the results of the HLT revision became HLT for the teaching experiment stage.

At the preliminary design stage, the initial HLT design was produced as follows

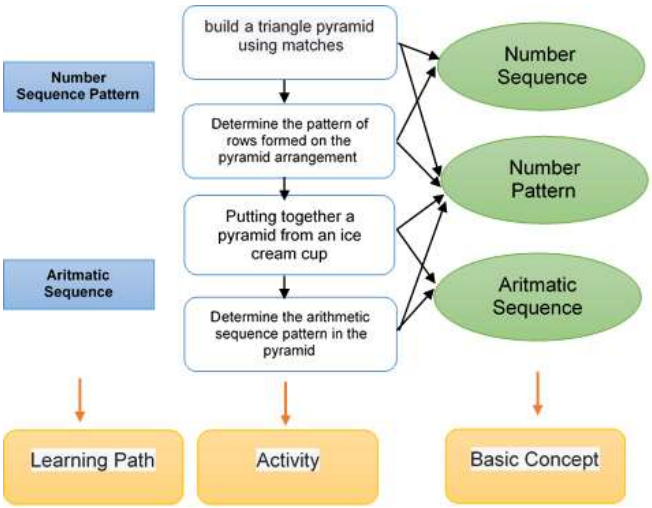

Figure 1. Student Learning Activity for Learning Aritmatics Sequence

3.2 Teaching Experiment

The aims of Teaching experiment was to try out the learning design and HLT that has been formulated. In this stage the teacher models teaching according to the HLT in Class X Office Administration 1 which consists of 19 students. Students are divided into 5 groups and each group consists of 3 to 4 students. This study was also equipped with 2 observers whose task was to observe class activities and fill out the observation sheets that were provided. The four activities that had been previously designed were tested. The activity of arranging the pyramid using matches, finding the pattern of lines formed in the pyramid arrangement, arranging the pyramid ice cream cup stack, and finding the arithmetic sequence pattern in the pyramid arrangement, then given a story problem to find out students' understanding of the arithmetic sequence concept that was found in the four activities previous. All activities were carried out in groups. Finally given a formal problem in the evaluation which was done independently.

3.3 Retrospective Analysis

This research used a PMRI approach where PMRI started from a context or a real problem experienced by students and then discussed in groups to find out for themselves and use mathematics to solve problems. This was the reason for answering the first problem formulation in this study, namely: What was the role of the PMRI approach in helping students find concepts in arithmetic sequence material?

The context used in this study was the context of the pyramid using existing tools such as matches and ice cream cups. This context was used to answer the first problem statement.

The first meeting emphasized the concept of a sequence of numbers with two activities, namely arranging the pyramid using a match and finding the pattern of sequences formed in the arrangement of the pyramid. Problems in this activity could be solved by most students correctly. From the results obtained by students, it could be seen that by arranging the pyramid in this learning process was very helpful for students to find patterns of numbers.

The second meeting was held to guide students to find the concept of arithmetic sequence with two activities, namely arranging the pyramid using ice cream cup and discovering the pattern of arithmetic sequence in the pyramid arrangement. In general, it could be concluded that this study showed that the use of the PMRI approach to the context of the building of the pyramid had important role in supporting the learning process of arithmetic sequences. The context of the pyramid building became the starting point in helping students understand basic concepts in arithmetic sequences. The problems associated with the activity made the pyramid attractive to students, so that they participated in a series of activities designed with enthusiasm. It was because students have seen and heard about pyramid buildings and became a realistic context for them.

The second problem formulation was a description of the learning trajectory of students in learning arithmetic sequences using the PMRI approach from the informal to the formal stages. Gravemeijer [10] mentioned four levels or levels in developing the model, namely the situational level, referential level, general level, and formal level. Descriptions were carried out starting from the development of students' abilities from pyramid formation to the formal stage of finding number patterns and determining arithmetic sequence patterns.

At the situational level in learning number pattern patterns, students used matches arranged into several pyramid models by identifying the number of triangles formed.

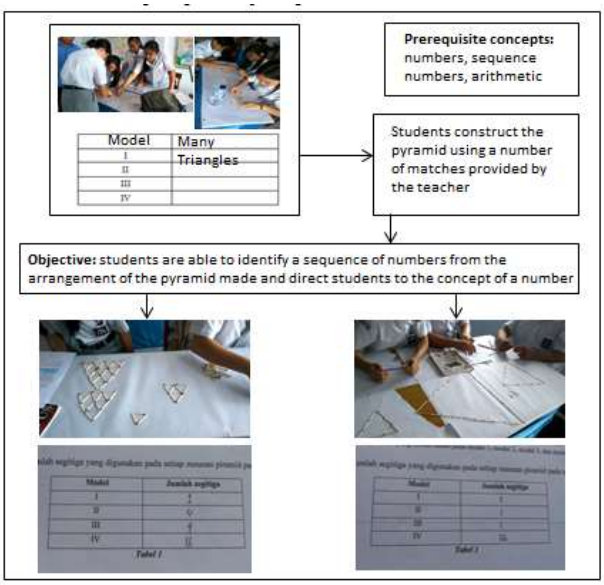

Figure 2. Students learning trajectory at the situasional level

At this situational level, there were two learning trajectories obtained. First the students arranged a match with a triangle arranged as expected. Such students had achieved the expected goal of the activity which was identifying the triangles formed at each arrangement of the pyramid. While on the other track, students arranged matches into large triangles. This was not in accordance with the objectives to be achieved, so it needed to be improved at the discussion stage. To complete the activity at this situational level, students must mastered the concepts of numbers, sequence numbers and arithmetic operations on numbers.

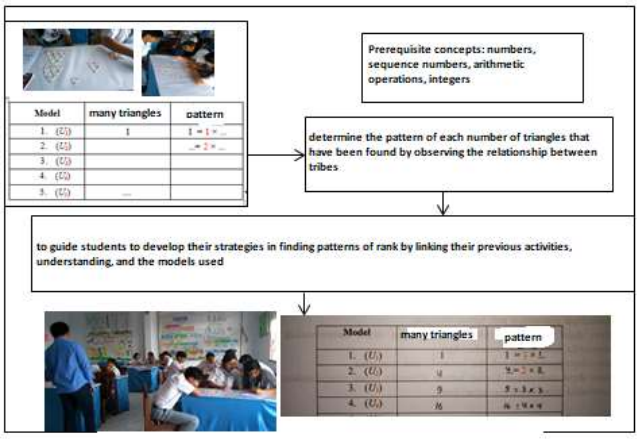

Figure 3. Student Learning Paths at the Referential Level

Learning trajectories obtained at this referential level was by using models found by students at the situational level, students compiled patterns of numbers based on the number of matches in each model. This showed the achievement of students in developing their strategies to form a pattern of ranks. The ability of students to

change the number of triangles into patterns showed the ability of students to change the context in a formal direction.

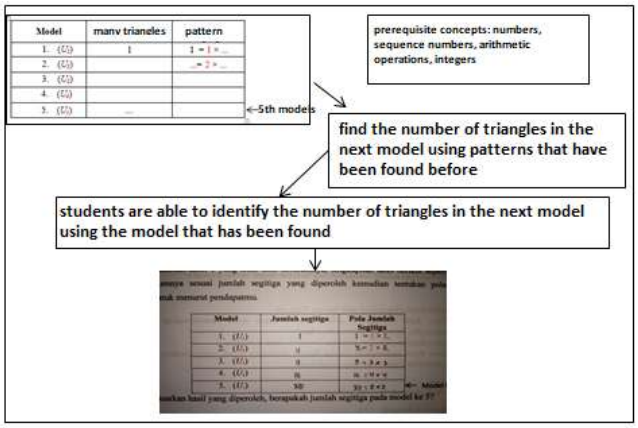

Figure 4. Student Learning Path at the General Level

The learning trajectory at the general level was shown by the ability of students to determine the number of triangles in the fifth model using patterns in the previous models. At this stage students used knowledge from previous levels to determine the next model.

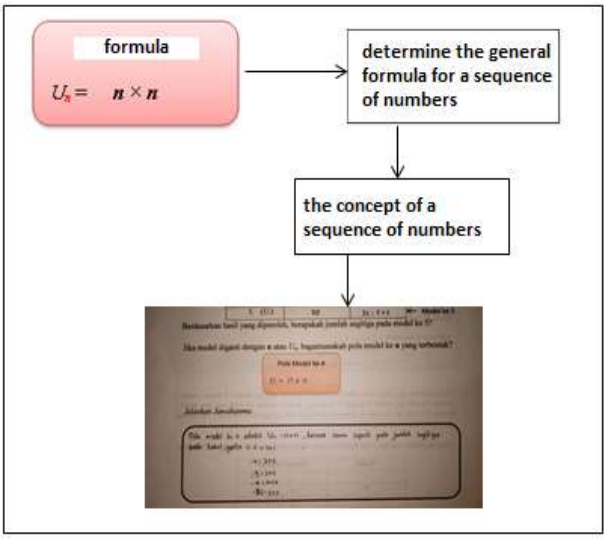

Figure 5. Student Learning Path at the Formal Level

At the formal level the learning trajectory obtained was to change the model and numbers at the previous level into mathematical symbols that lead to the concept of a number sequence. At this stage students was able to find a general pattern of numbers that could be used to determine any number of sequences.

Situational level in learning arithmetic sequence, students still used the pyramid but this time arranging the pyramid using ice cream cup with 5 different models. In this activity, after students arranged the pyramid, students counted the number of cups used in each arrangement of the pyramid. At this stage students got a number of different cups served as a bridge from the informal to the formal stages.

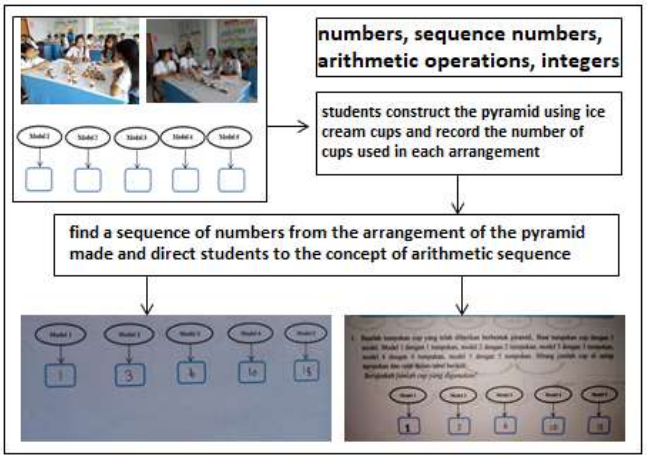

Figure 6. Student Learning Path at the Situational Level of Arithmetic Row

There were 2 learning trajectories obtained at this situational level, namely the first student was able to find a sequence of numbers through the arrangement of the pyramid using the ice cream cup in accordance with the expected goals. Second, students found another row with a different pyramid stack on the first model. In order to be well directed at the next stage, this was discussed in the discussion and the same sequence was obtained.

Learning trajectory at the referential level where students determined the difference between rows of numbers so that they found a new sequence that was the basis for finding the concept of formal arithmetic sequence.

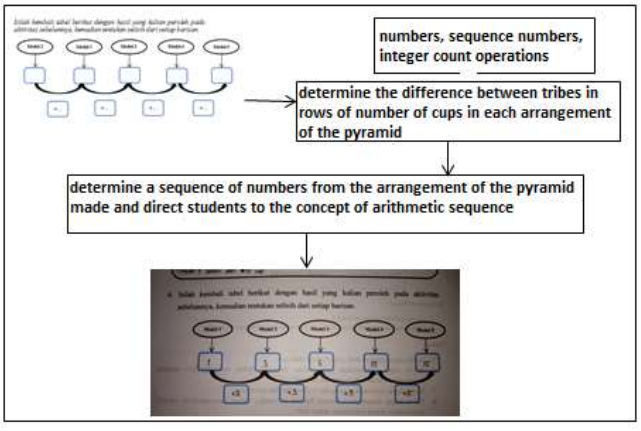

Figure 7. Learning Paths of Students at the Arithmetic Line Reference Level

At the general level, the learning trajectory obtained was that students able to determine the same difference from the ranks obtained at the previous level. From this activity, students had directly found the basic concept of

arithmetic sequence, the row with the same difference between adjacent tribes. Mathematical ability must be mastered by students to arrive at this level was the ability about numbers, sequences of numbers, and operations to calculate numbers.

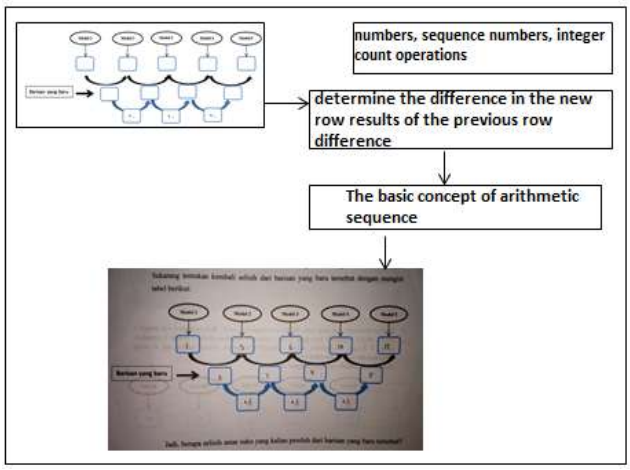

Figure 8. Student Learning Path at the General Level of Arithmetic Line

There were 2 learning trajectories obtained at this formal level, namely first students found the pattern of arithmetic sequence to find the general pattern of the nth model of arithmetic sequence. This showed the achievement of understanding the concept in accordance with the objectives expected in this study. The second track, students were able to find patterns of arithmetic sequence but had not been able to make a general pattern of the nth model of arithmetic sequence. This means students had not been able to connect previous patterns with the general patterns in question. The results obtained were discussed by all students together with the teacher to equalize students' views and findings.

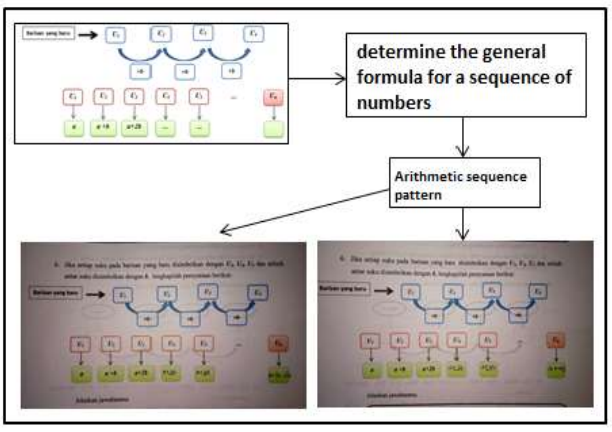

Figure 9. Student Learning Path at the Formal Level of Arithmetic Row

4. CONCLUSION

The use of the PMRI approach provided an important role in supporting and motivating students in learning arithmetic sequences. Students were enthusiastic and paid close attention when participating in learning activities carried out. From classroom learning activities, the use of PMRI's approach to the context of the pyramid lead students to discover the basic concepts of arithmetic sequence.

Student learning trajectory in learning arithmetic sequence developed from the informal to the formal stage. In the situational stage in learning the pattern of number sequences, students used matches arranged into several pyramid models by identifying the number of triangles formed. Whereas in the referential stage students compiled a pattern of the number of triangles obtained in the previous stage then explained their answers. At the general stage students were directed to find the number of triangles in the next model without constructing the pyramid again, this was the basis for the results found by students themselves who become the general stage (model for). Achievement of students to present patterns in the form of general patterns of the nth model showed the ability of students to the formal level. In arithmetic sequence learning, the use of a pyramid context using an ice cream cup was the starting point for the informal stage. At the situational stage students compiled several pyramid models using ice cream cups then students recorded the number of cups used in each pyramid arrangement. The student's referential stage determined the difference in the number of cups in each model so that students found a new line. Whereas in the general stage the students found the difference in the new sequence which was the basic concept of arithmetic sequence. Formal stage was shown when students were able to find general patterns of arithmetic sequence based on the results they got at the general stage. After discovering arithmetic sequences concepts, students could solve problems at the formal level using their knowledge and experience in the previous stages.

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