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Learning The Permutation Concept Through Role-Playing

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Article Info	ABSTRACT
	This research aimed to produce a learning trajectory which could help students to understand the concept of permutations through role-playing activity in the election of chairman and vice-chairman of Intra School Students Organization. This research was a design research method through three stage, 1) preliminary design/preparing for the experiment were used to design the Hypothetical Learning Trajectory, 2) design experiment was a Hypothetical Learning Trajectory test phase consisting of pilot and teaching experiment, 3) retrospective analysis. It was Indonesia's Realistic Mathematics Education Approach at tenth grade of Senior High School No 15 Palembang. Data collecting technique were obtained from observations, recorded videos, photos, students' sheet activities, and field documentation. The result of this research was a learning trajectory which has three activities that could help student to understand the concept of permutations, there are: 1) the students could determine the form of administrative committee and calculate the number of formed groups formation in the election from 2, 3, 4 and 5 nominated candidates, 2) Students could determine the number of groups' formation convert into the closest form of the multiplication and the factorial, 3) by using the students understanding of factorial, students found the concept of permutations form: $nPr = \frac{n!}{(n-r)!}$

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1. INTRODUCTION

The students' ability in understanding the problems of permutations study is still considered very low [1]. The cause of the students' difficulties in solving the permutation problems is that they are confused to use permutations formulas or combinations of formula in solving the problem of enumeration rules, Thereby, the presentation of the material from the mathematics learning books always made the students to follow the examples of problem-solving that exist. Typically, when the question is changed, it will make students feel confused in determining the concept of problem-solving [2]. The students' low achievement in learning mathematics was caused by some factors, such as an uninteresting presented learning material and the lack of examples of application in everyday life, as well as during the learning process, the implemented teaching method was mainly focused on teacher-centered activity only throughout class time [3]. In the process of learning mathematics, the students were generally directed at the process of memorization rather than in understanding the learning concept of mathematics [4].

As stated in the Standards of Graduate Competency of *Permendiknas* No. 21 the Year 2016, permutations study is an important learning material to be learned, that students must be able to solve the contextual problems related to permutations [5]. The importance of studying the concept of permutations study is to learn the bases of one kind of combinatorial analysis [6], and it could be applied in daily life, for example in scheduling procedure [7].

Fundamentally, an appropriate alternative learning is needed to improve students' understanding toward the concept of permutations study, as well as the importance of these permutations materials in the learning process and students' life in every day. One alternative could be used in studying permutations materials is that students need real-life problems in a more relevant context, which can stimulate the students' interest in learning and maintain their prior knowledge [8].

One of the learning approaches that could be used by teachers of mathematics in developing students' ability to think, understand, communicate, and solve the problems in both the learning process and daily life is that by using Indonesia's Realistic Mathematics Education approach [9]. It was developed as Indonesian version since 2001. It was taken from Realistic Mathematics Education developed by Freudental Institute in the Netherlands, and its concept was adapted to Indonesian culture and based on the theory of Realistic Mathematics Education [10]. There are 3 principles of Indonesian Realistic Mathematics Education in the learning process; (1) guided reinvention and progressive mathematizing, (2) didactical phenomenology, and (3) self-developed models [11].

Furthermore, the recent research has a positive result, that the use of Indonesia's Realistic Mathematics Education approach with the barcode context could improve students' understanding of the concept of enumeration rules [12]. In line with this, Indonesia's Realistic Mathematics Education could lead students in understanding the mathematical concepts by constructing their background knowledge related to everyday life in such a "real" situation [13].

In addition, the concept of playing the game could create situations related to the students' real experiences as well as phenomena and events in the environment, which could be used as starting points/opening activities/series of activities for learning [14]. Permutations study could be solved by using playing game [15], and it could be taught through exchange-places game [16].

One kind of playing game activities that could be played by students in learning permutations study is role-playing activity in the election of chairman and vice-chairman of Intra School Students Organization. It is the best way to develop skills, initiative, communication, problem-solving, self-awareness and cooperative work in groups [17]. Intra School Student Organization is one of the organizations that exist in Junior High School and Senior High School in Indonesia, which used to determine the chairman through the conducted election followed by all students and teachers. The period of management of the Intra School Student Organization would be held in every year; thereby it should be a change of leadership. It is hoped that through role-playing activity in the election of chairman and vice-chairman of Intra School Student Organization could raise possibilities and a large number of formed groups as expected to help the students to understand the concept of permutations study.

2. RESEARCH METHOD

The kind of this research was a "Design Research", which designed to produce a learning trajectory on permutations study by using the context of role-playing activity in the election of chairman and vice-chairman of Intra School Students Organization. It is a form of research that aimed at developing Local Instructional Theory with the cooperation between the researcher and the teachers to improve the quality of learning [18]. In this research, the developed design was Hypothetical Learning Trajectory, which contained a series of students' learning activities. There are three stages in this research design: preparing for the experiment, design experimental, and retrospective analysis [19]. This article will describe the results of research at the design experimental stage (teaching experimental group). The research stages are shown in Figure 1 below.
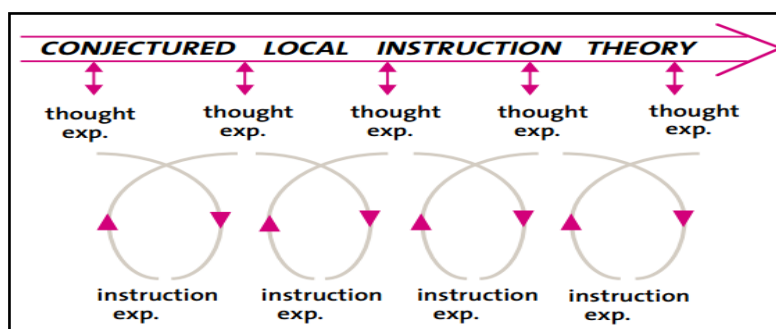

Figure 1.The Process of Designing Research [20]

Data collecting technique in this research were obtained from recorded videos at the study process, students', and activity photos, and the result of student's activity in students' sheet activities. The stage of presentation of learning video result data by transcribing into the written form.

3. RESULTS AND ANALYSIS

This research was designed for produced learning trajectory which can help students to understand the concept of permutation through role-playing of election chairman and vice-chairman of Intra School Student Organization. It was implemented at tenth grade of Senior High School No 15 Palembang with six students at pilot experiment step and 36 students at teaching experiment step. The following is the result of the study:

3.1. Preparing for the Experiment

First step, researcher reviewed all literature to produce Hypothetical Learning Trajectory of permutations learning with the through role-playing of the election chairman and vice-chairman of Intra School Student Organization, which is: reviewed standard content based on curriculum K13 with basic competencies understanding the concept of permutation, reviewed Indonesia's Realistic Mathematics Education Approach, and design research as a method of that used in this research. The Following Hypothetical Learning Trajectory has been designed which can be seen in the following figure 2:
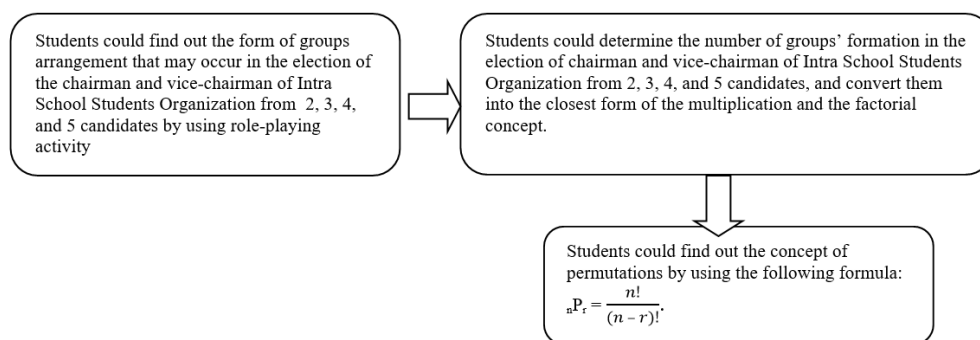
Students could find out the form of groups arrangement that may occur in the election of the chairman and vice-chairman of Intra School Students Organization from 2, 3, 4, and 5 candidates by using role-playing activity

Students could determine the number of groups' formation in the election of chairman and vice-chairman of Intra School Students Organization from 2, 3, 4, and 5 candidates, and convert them into the closest form of the multiplication and the factorial concept.

Students could find out the concept of permutations by using the following formula: $_nP_r = \dfrac{n!}{(n-r)!}$.

Figure 2. Hypothetical Learning Trajectory

3.2. Design Experiment

The second stage, design experimental that consisted of two cycles; cycle 1 as the experimental pilot and cycle 2 as the experimental treatment. In cycle 1, the researcher acted as model teacher and tested the Hypothetical Learning Trajectory to the six students apart from the students who became the subject of the research at the time of conducting the research cycle 2. Those six students were selected based on the level of ability; 2 high ability students, 2 students with medium ability, and 2 students with low ability. Meanwhile, in cycle 2 of experimental treatment, the researcher acted as an observer. In this cycle, the teaching and learning process was under the mentoring of their own teacher as the model teacher to take control in this class, and there are 36 involved students of Senior High School Number 15 Palembang in the learning process. Following explained the result of the research at the teaching experiment of cycle 2:

Students can determine the form of group formation that may occur in the election of the chairman of Intra School Students Organization from 2, 3, 4, and 5 candidates by using role-playing activity

In the first activity, the students were asked to play *"Role Playing"* game in solving the election problems of the management of Intra School Students Organization, and they were asked to find out how likely the chairman and vice-chairman that might be formed from 2, 3, 4, and 5 nominated candidates in the Intra School Students Organization election. At the beginning of this activity, the teacher has divided the students' groups into six (6) groups that consisted of six students in each group, then the students have chosen one of their members to be the candidate of chairman and vice-chairman in the Intra School Students Organization election. The chosen students played their role as the chairman and vice-chairman candidates while the other member students participated to vote the chosen one.

In order to determine the two (2) candidates to be nominated at the first activity, the students have written the name of candidates students on the Students' Activity Sheet and put it into a provided box. After that, the election of chairman and vice-chairman of the Intra School Student Organization were decided by group members who served as observers by looking at the possible form of arrangement from the 2 candidates. The transcript of the conversation can be seen as follows.

Transcript 1

Teacher : *Please...your group explain the answer to the problem no 1. Who will be the candidates from your group?*

Student : *The candidates of our group are Khairul and Inayah Salsabilah.*

Teacher : *Then, determine the administrative arrangement that may occur in the chairman and vice chairman election of Intra School Students Organization?*

Student : *The chairman candidate is Khairul Ihsan and the vice-chairman candidate is Inayah Salsabilah (Both of students hold the paper with the names of each corresponding position directly)*

Teacher : *Are you sure if they are as the candidates from your group?*

Students: *We have voted them Ma'am.*

Teacher : *So, how many possible forms of arrangement from these 2 candidates?*

Students : *Only one form of arrangement.*

Teacher : *Then? Is there any form of arrangement?*

Students : *Hmmm (Thinking...)*

Teacher : *Please... practice one more time?*

Student : *Oh... there is another possible arrangement, Inayah salsabilah can be as a chairman and her vice-chairman is Khoirul Ihsan (Both of them hold the paper with the names of each corresponding position directly)*

Teacher : *What do you think if there are two possible candidates?*

Student : *There are two formed arrangements. In the first arrangement, Khairul Ihsan can be as the chairman and his vice-chairman is Inayah Salsabila, Meanwhile, in the second arrangement Inayah Salsabilah can be as the chairman and KhairulIhsanas her vice-chairman.*

Teacher : *So, they exchange their position one another?*

Students : *Yes, they do.*

Teacher : *Is there another formed arrangement beside those two arrangements?*

Students : *no...nothing.*

In the election, each group has different ways to give their votes, one of the ways is by giving the most votes of group members to the non-candidates of chairman of Intra School Students Organization, the student who got the most votes, he/she acted as the elected chairman by holding a paper with the name as a chairman. Meanwhile, the student who got the least votes, he/she acted as a vice-chairman by holding the name as vice-chairman. Then, the teacher guided the students to see if there are any possible group formations that can be formed. To determine other arrangements, the student exchanged his/her position and roles. For example, if A is chosen as the chairman then B will become the vice-chairman, meanwhile, if B is chosen as the chairman then A will become as co-chairman. In other words, that the arrangement of permutations could be $AB \neq BA$.

Furthermore, the results of students' answers to this first activity showed that by using role-playing activity, the students are able to determine the possible group formations in the election of chairman and vice-chairman of Intra School Students Organization. Further, there are no serious obstacles experienced by students while carrying out this activity. If there are 2 candidates of the board then the number of formations that can be formed is 2 forms of arrangement, if there are 3 candidates then the number of formations that can be formed is 6 forms of arrangement, if there are 4 candidates then the number of formations that can be formed is 12 forms of arrangement, and if there are 5 candidates then the number of formations that can be formed is 20 forms of arrangement. Some students' group answer in solving the election problems if there are 2, 3, 4, and 5 possible candidates can be seen in Figure 3 below.

Figure 3.The result of the student's answer in determining the possible groups'formation in the election of chairman and vice-chairman of Intra School Students Organization

Students can determine the number of groups' formation in the election of chairman and vice-chairman of Intra School Students Organization from 2, 3, 4, and 5 candidates, and convert them into the closest form of the multiplication and the factorial concept.

In the second activity, the students were asked to calculate the number of formed groups formation in Student Intra School Organizations election from 2, 3, 4 and 5 nominated candidates. The students' success in determining the number of the groups' formation was based on the results of their first activity. For example, if there are 2 candidates, then there are 2 formations exist, if there are 3 candidates, then there are 6 formations exist, if there are 4 candidates, then there are 12 formations exist, and if there are 5 candidates, then there are 20 formations exist. Moreover, in this activity, the students were asked to convert the number of groups that they have found into the closest form of the multiplication. Further, there is no constraint experienced by the students in converting the number of formations into the closest form of the multiplication. The transcript of the conversation between the teacher and students can be seen as follows.

Transcript 2
Teacher : *Try to explain if there are 20 arrangements converted into the closest form of multiplication, and how do you form its shape?*
Student : *It is 4 x 5 or 5 x 4*
Teacher : *How do you know*
Student : *It's about the closest multiplication form Ma'am, After number 4, it is followed by number 5, and if 4 x 5 or 5 x 4 the result is 20.*

In this activity, the students can explain the result of their answers that they have found; for 20 formations, it could be converted into the closest multiplication with 4 x 5 or 5 x 4, for 2 formations, it could be converted into the closest multiplication with 2 x 1 or 1 x 2, for 3 formations, it could be converted into the closest multiplication with 2 x 3 or 3 x 2, and for 12 formations, it could be converted into the closest multiplication with 4 x 3 or 3 x 4. The aim of this activity is to facilitate the student to find the concept of factorial because in the next activity the students would be asked to convert the form of the closest multiplication into the form of the factorial concept. The result of students answer in factorial form can be seen in the following Figure 4.

Figure 4. The results of student answers in the factorial form

Based on the result of students' answers, it showed that students are able to convert the number of group formations that they have found into the closest form of the multiplication, there is no constraint experienced by students in converting the number of formations into the closest form of the multiplication. In other hands, the result of multiplication 5 x 4 could be converted into factorial form with $\frac{5!}{3!}$, the result of multiplication 2 x 1 could be converted into factorial form with $\frac{2!}{0!}$ or $\frac{2!}{1!}$, the result of multiplication 3 x 2 could be converted into factorial form with $\frac{3!}{0!}$ or $\frac{3!}{1!}$, and as the result of multiplication 4 x 3, it could be converted into factorial form with $\frac{4!}{2!}$.

Students can find the concept of permutations form: nPr = $\frac{n!}{(n-r)!}$

The third activity, to make it easier for students in determining the general concept of permutations, the students were required to summarize all the results of activity 1 and activity 2 into an available table on the Students' Activity Sheet. In this activity, the teacher guided the students to find out the general concept or the permutation formula by converting the form of the factorial pattern to the general concept of permutations by utilizing the number that exists on the most candidates and the number that exist on many positions object. The transcript of the conversation between the teacher and the students in finding the general concept of permutations and/or its formula was presented as follows.

Transcript 3
Student : *There are only 2 nominated candidates at the beginning.*
Teacher : *How many chosen positions object?*
Student : *Only 2 positions*
Teacher : *What?*
Student : *There are two corresponding positions, namely the chairman and vice-chairman of Intra School Students Organization.*
Teacher : *Ok, how many formed groups arrangement we have....?*
Students: *2*
Teacher : *Are the form still in the same kind of that multiplication?*
Students: *Just move its position.*
Students : *Where is it?*
Student : *2 multiplied by 1 (2 x 1), it is in form of factorial.*
Students: *Two factorials per nol*
Student : *How about in form of permutations?*
Teacher : *Try to write again those two factorials, per?*
Students: *Nol*
Teacher: *How do you get nol?*
Students : *(Thinking)*
Student : *By multiplying 1 and 0 (it's the result of 1 x 0)*

Teacher   : *In this point of view (look at the number of the most nominated candidates in the column and the number of positions of the object in the table?)*
Students : *"from" (thinking)*
Student   : *Yups... 2 reduced by 2 (2 - 2)*
Teacher   : *Okay, please write it now?*

In this activity, the student succeeded in finding the general concept of permutations still in form of the numbers, the result of student's answer in the form of factorial concept $\frac{2!}{0!}$ was converted to $\frac{2!}{(2-2)!}$ by changing 0! to (2-2)!, it was obtained from 2 numbers in the column of many candidates which was reduced by 2 numbers in the column of many position objects. For the next permutation pattern, students initially wrote $\frac{3!}{0!}$ in the factorial concept column, but after the student subtracts the 3 numbers in the column of many candidates with 2 numbers in the column of many objects, then the result was 1, thereby the students wrote $\frac{3!}{1!}$, then it was converted to permutations of form $\frac{3!}{(3-2)!}$. Moreover, in the next steps the students converted $\frac{4!}{2!}$ to $\frac{4!}{(4-2)!}$, and $\frac{5!}{3!}$ to $\frac{5!}{(5-2)!}$

Furthermore, the teacher guided the students to find out the general concept or formula of permutations that were already in the form of symbols. The following conversation is the discussion result between the teacher and the students in determining the general concept of symbolized permutations.

Transcript 4
Teacher : *Okay, please look at the number! There are 2, 3, 4, and how do you symbolize it?*
Students : *Eeehm those (Thinking), "n".*
Teacher : *Alright, then try to write what n it is?*
Students : *"n" factorial. This is, "per" inside the bracket "n" min "r" for the closed bracket factorial ($\frac{n!}{(n-r)!}$).*

The result of the students' answers in the determining the concept of permutations is shown in Figure 5.

Figure 5. The students'answer in determining the permutations concept

From the result of the student's answer, it showed that the students are able to understand the concept of permutations by using role-playing activity with the model teachers' instruction, and finally, the students could find out the permutations formula $_nP_r = \frac{n!}{(n-r)!}$.

3.3. Retrospective Analysis of Teaching Experiment
In this study, the students' exchanged roles and positions as elected chairman and vice-chairman of the Intra School Students Organization could generate a sequence of management formations in the election. The students' activity is in line with the definition of, that permutations study is an arrangement of sorted objects [21]. In the subsequent activity, the students found out the number of formations of board

management that can occur in the election of chairman and vice-chairman of Intra School Students Organization from 2, 3, 4, and 5 nominated candidates. This shows that students' was very enthusiastic to do role-playing activity and shows that permutation could be learned through role-playing. In this study, to find out the general concept of permutations study, the students determine the number of board management that can occur from the "r" object in many needed positions by paying attention to "n" objects of all existing candidates. Herein, the students could find the general concept or the formula of permutations $\frac{n!}{(n-r)!}$. Based on the result of the retrospective analysis in the activity 1, activity 2, and activity 3 of cycle 2 (teaching experiment), that the learning procedure was in accordance with the designed Hypothetical Learning Trajectory. It can be concluded that the students have understood the concept of permutations study via the role-playing activity in the chairman and vice-chairman election of Intra School Students Organization by determining the possible board management and the number of formed groups.

4. DISCUSSION

In this research, learning trajectory that has been designed and done by the researcher to understand the concept of permutations was through role-playing to the election the chairman and vice-chairman of Intra School Student Organization that has three learning activities that has been done at the process of students' learning. This learning process reflected three principles of Indonesia's Realistic Mathematics Education. Three principles of Realistic Indonesia's Mathematics Education are guided reinvention and progressive mathematizing, didactical phenomenology, and self-developed models [11]. Based on the guided reinvention principle in this permutations learning process, the students were given equal opportunity to play the role of determining the form of chairman and vice-chairman of Intra School Students Organization in their own way through the direction and guidance of the teacher. Hereby, those students have their own learning experience activities.

The second principle is didactical phenomenology. This principle stated that the situation with the phenomenon used as material and application area in the teaching of mathematics must depend on the real context of the students' background before they can reach the level of mathematics formally, it means that realistic mathematics teaching emphasizes the importance of the contextual problems to introduce the mathematical topic to the students. The use of the context of chairman and vice-chairman election in Intra School Students Organizations is a contextual problem that existed in the students' life as a phenomenon in the concept of permutations study because students can have the experience in the election of the board management of Intra School Students Organization.

The third principle is self-developed models in this principle; the developed model by the students is used to serve as a bridge of informal knowledge to formal mathematics. It can be seen from students' activity in determining the board management that may occur, such as determining the number of group management, converting the formations into the form of the closest multiplication, in turn, it is converted to the form of the factorial concept, and at last, the students were able to find out the permutations formula as a result of students' understanding of the permutations study concept.

5. CONCLUSION

Based on the findings of this research and its discussion, it can be concluded that the encountered learning trajectory consisted of 3 activities: Activity 1, the students could determine the form of administrative committee and calculate the number of formed groups formation in the election from 2, 3, 4 and 5 nominated candidates. Activity 2, students could determine the number of groups' formation convert into the closest form of the multiplication and the factorial. Activity 3, by using the students understanding of factorial, students found the concept of permutations form: $nPr = \frac{n!}{(n-r)!}$. Moreover, the findings showed that by using role-playing in the election of the chairman and vice-chairman of Intra School Students Organization could help students to understand the concept of permutations study.

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