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DEFRAGMENTING STUDENT'S THINKING STRUCTURES IN SOLVING MATHEMATICAL PROBLEMS ON PISA MODEL

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ABSTRACT

Problem solving is defined as a series of activities that allow students to find solutions to problems. Students' thinking processes occur when processing data or information to solve problems. One way to help students maximize the thinking skills is to make their experience when solving problems with PISA model. But in reality, Students made many mistakes and have difficulty understanding the problem, making a settlement plan, lack knowledge of the prerequisite material, and have not been able to describe the reasons in detail regarding the solutions found. One of the possible solutions to improve and complete the structure of students' thinking in solving mathematical problems on the PISA model HOTS questions is defragmenting. This study aims to describe the changes of students' thinking structure in solving mathematical problems through defragmenting. This type of research is descriptive research with a qualitative approach. The research data consisted of students' answers, the results of thinking aloud, and the results of semi-structured interviews. The results showed that students experienced assimilation at the stage of understanding the problem, while at the stage of formulating strategies, implementing plans, and re-examining students' thinking processes, they experienced accommodation. This is because students need defragmenting to connect mathematical concepts to solve problems, correct errors, and complete incomplete problem solving steps.

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INTRODUCTION

Problem solving is defined as a series of activities that allow students to find a solution (Tambunan, 2019; Tippmann et al., 2017). Problem solving is also a process that students do to overcome a problem through stages, including defining the problem, finding out the factors that cause problems, finding solutions, and applying these solutions so that the problem can be solved (Gog et al., 2020). Problem solving is very important to master because students will encounter various types of problems both in the learning process and in everyday life

(Mathew et al., 2019). Problem solving is a competency that must be prioritized for students so that they can apply and adapt strategies to solve other problems in different contexts (Halpern, 2014).

In solving mathematical problems, of course students' thinking processes occur when processing data or information to solve problems (Hamdani et al., 2021). The thinking process includes the process of receiving information, managing, storing, and recalling that information through students' memories (Demirel et al., 2015; siti Rochana, 2018). This explains that when students think, they must carry out a process to make decisions and resolve problems they find (Dorko, 2019). Thinking is the process of understanding various things encountered in everyday life, finding certain opinions or ideas, making judgments and solving problems. One of the tasks that teachers must do in learning mathematics is to help students maximize the thinking skills they experience when solving problems (Bormanaki, 2017). One way is by giving non-rotative questions, namely PISA questions.

PISA or Program for International Student Assessment, is an international study that is held every three years to test the higher-order thinking skills of students who have an average age range of 15 years (Supiarmo et al., 2021; OECD, 2013). This study was conducted by giving questions that emphasized the competencies and skills possessed by students through formal schools and their implementation in everyday life (OECD, 2014). The PISA math questions tested consisted of three components, including content, process, and context (Supiarmo et al., 2021; OECD, 2013).

The problems in the PISA questions emphasize not only the ability to apply concepts, but also how the concepts are applied in various situations (OECD, 2014). In addition, the PISA questions tested include formulating problems, analyzing, doing mathematical modeling, making comparisons related to various problems to be solved, and solving problems using algorithms, so the PISA questions become a barometer to determine the achievement of students' higher order thinking skills (HOTS). throughout the world, including Indonesia (OECD, 2013).

Indonesian students' mathematics achievement related to HOTS ability is still in the low category. This is based on the results of PISA, which confirms that the abilities of Indonesian students at levels 4, 5, and 6 are in the poor category, where at that level the focus is on students' abilities in formulating, identifying, reflecting, formulating, applying, interpreting, and answering using algorithms. A procedural solution Therefore, a solution is needed to overcome the low HOTS ability of students. One of the efforts made by the Indonesian government is to form a PISA-equivalent question development team. The institution assigned was the Indonesian Realistic Mathematics Learning Team (PMRI) to make PISA model HOTS questions. This is done to introduce Indonesian students to the types of PISA questions so that they can support students' ability to compete in global PISA competitions.

But in reality, students still have difficulty solving the PISA model HOTS questions. This is evidenced by the results of an initial study conducted by researchers in class XII of Islamic Senior High School Maraqitta'limat Mekar Sari, which showed that students made a lot of mistakes in solving the PISA model HOTS questions. In addition, based on the results of interviews with mathematics teachers at the school, they explained that errors were caused because students had difficulty understanding problems, making plans for completion, lack of knowledge of prerequisite material, and not being able to explain in detail the reasons related to the solutions found. Thus, this problem is the cause of problems with students' thinking schemes related to errors in solving problems (Bahrudin et al., 2019; Dorko, 2019;

Tambunan, 2019). Therefore, appropriate treatment is needed to rearrange and improve the thinking structure related to the student's mistakes. One possible solution to improve and complete the structure of students' thinking in solving mathematical problems on the PISA model HOTS questions is defragmenting.

Defragmenting is described by Kumalasari et al. (2016) as a stimulus given to students in order for them to rearrange their thinking structures or undergo cognitive restructuring by changing their thinking structures to become regular and realistic. So, through defragmenting, students' thinking structures can be improved, especially in solving mathematical problems. Defragmenting can be done through disequilibration, cognitive conflict, and scaffolding, which are proven to be able to improve students' thinking schemes to be more logical and systematic (Taufiq Hidayanto, 2017).

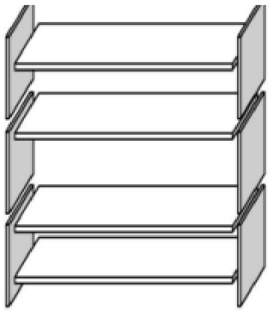
Several studies on defragmenting thinking structures have been carried out, including the research of Muhtadin (2020) which provides a defragmentation of students' thinking processes in solving story problems. Research by Bahrudin et al. (2019), defragmenting students' thinking processes in solving the problem of flat shapes. Hidayanto's research (2017) shows that defragmenting students' thinking processes in solving mathematical problems, especially geometric problems, is essential.

The defragmenting in this study aims to improve and rearrange the structure of students' thinking in solving problems based on the PISA model HOTS questions. This is done by providing feedback in the form of disequilibration, cognitive conflict, and scaffolding, which stimulates students to improve and complete the thinking stages optimally. Until now, there has been no research on the analysis of changes in students' thinking schemes in solving non-routine questions, especially the PISA model HOTS questions. Therefore, The purpose of this study was to determine transformation in the structure of students' thinking in solving mathematical problems on the PISA model HOTS questions through defragmenting.

METHOD

This type of research is descriptive research with a qualitative approach. The prospective subjects involved were 31 grade XII students of Islamic Senior High School Maraqitta'limat Mekar Sari. The selection of subjects in this study was carried out by purposive sampling techniques. Students are first given problem solving problems related to linear programming. When students are grouped based on the category of problem solving abilities, including low, medium, and high. Furthermore, the researchers chose 2 subjects with low problem solving abilities. These two subjects were provided with the following HOTS questions of the PISA model developed by the PMRI team (2011).

1. Untuk membuat rak buku seorang pengrajin memerlukan bahan sebagai berikut.
   - 4 buah papan kayu panjang
   - 6 buah papan kayu pendek
   - 12 penjepit kecil
   - 2 penjepit besar
   - 14 buah sekrup



Pengrajin tersebut menyimpan stok 26 papan kayu panjang, 33 papan kayu pendek, 200 penjepit kecil, 20 penjepit besar dan 510 sekrup. Coba pikirkan berapa banyak rak buku yang mungkin dapat dibuat oleh pengrajin itu?

Figure 1. PISA Model HOTS Problem

The data in this study consisted of student answers, think aloud results, and semi-structured interviews. subject research data was analyzed to determine the lack of students' thinking processes in solving problems. This is known through errors and incomplete algorithms, so it becomes a guideline for researchers to carry out defragmenting. Data on students' thinking processes before and after defragmenting mathematical problems were analyzed through Piaget's (1959) theory of change in thinking schemes, namely accommodation and assimilation. The analysis technique is carried out through stages, including data reduction, data presentation, and conclusion drawing.

RESULTS AND DISCUSSION

Results

The research subjects were students with low problem solving abilities, represented by S1 and S2. Both subjects experienced problems in solving problems on the PISA model HOTS questions, so defragmenting was done to overcome them. The changes in the thinking schemes of the two subjects will be described based on changes in Piaget's (1959) thinking scheme, namely assimilation and accommodation, which are described as follows.

a. Defragmenting S1 Thinking Structures in Solving Mathematical Problems on Pisa Model HOTS Questions

S1 is a subject who has low problem solving ability. S1 can describe the problem in a simpler way, but S1 is not able to relate the problem to mathematical material to solve the problem. This is because the thinking structure of S1 does not match the problem given. More details can be seen in Figure 2.

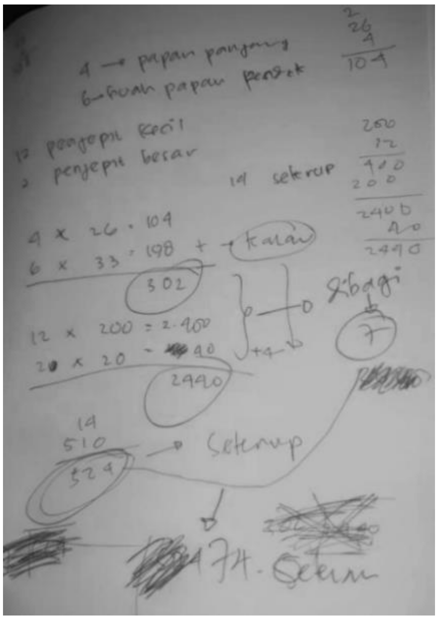


Figure 2. S1 Answers Before Defragmenting

Based on Figure 2, it can be seen that at the stage of understanding the problem, S1 experienced assimilation. This is because S1 can directly describe the problem as being simpler even though it is not complete. In a study conducted by Supiarmo (2021), it is stated that when experiencing assimilation, a person does not change or replace the existing schema because the structure of the problem encountered is compatible with the schema he has. Based on the results of think aloud and interviews, S1 can explain that to make 1 bookshelf it takes 4 long blackboards, 6 short wooden boards, 12 small clamps, 2 large clamps, and 14 screws. In addition, S1 is also able to explain the stock of materials available for making shelves through interviews. These results prove that S1 can simplify the problem by describing the known information. However, S1 did not fully understand what was asked in the given question, so when asked to explain, S1 looked confused. Halpern (2014) explains the stage of understanding the problem includes the ability to describe important elements related to information that is known and asked in the problem.

Problem S1 who is not able to fully understand what is being asked in the problem, also has an impact on the next step, where S1 experiences accommodation at the stage of formulating a strategy. Accommodation occurs because S1 requires defragmenting to relate the problem to the mathematical concepts that have been studied in order to solve the problem. According to Dorko (2019), accommodation occurs when cognitive structures are adapted through new experiences, resulting in the formation of new schemes or changing old schemes caused by the treatment given. Based on Figure 2, S1 performs a multiplication operation between the number of materials needed to make 1 bookshelf and the total available materials. Then S1 adds up the multiplication results without having a clear reason. These results indicate that S1 does not know what materials can be used, so they cannot determine the right strategy to solve the problem. In the research of Haseski et al. (2018) and King (2019), it was stated that strategizing is the stage of interpreting formulas based on concepts or materials that are appropriate and possible to be used to solve problems.

Next, the researcher used defragmentation to stimulate S1 to recall the right math material to solve the problem. The defragmenting given is in the form of a stimulus related to how S1's knowledge of linear programming material is and how to solve problems related to linear programming. Through the defragmenting, S1 can recall mathematical knowledge, especially linear programming material, precisely in determining the maximum value for making bookshelves. Thus, after defragmenting, S1 is able to connect mathematical material, especially linear programs, to solve problems. This is in accordance with the theory of connection knitting (Subanji, 2015), which creates connections between thinking structures so that students are able to develop strategies to build solutions. The snippet of S1's answer after defragmenting can be seen in Figure 3.

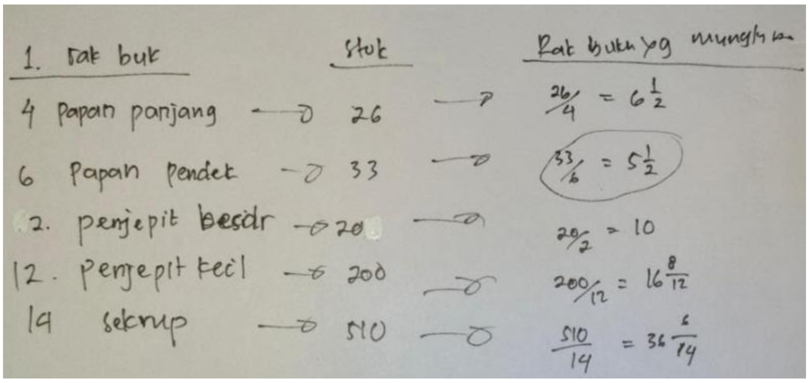


Figure 3. S1 Answer Pieces After the First and Second Defragmenting

Based on Figure 3, it is evident that at the stage of implementing the S1 plan, accommodation is experienced. This is because S1 requires defragmenting through cognitive conflict to determine how much of each material might be used to make a bookshelf. After being given defragmentation, S1 divides the total available materials with the materials needed to make 1 bookshelf. As for the results of the division, it is obtained that the maximum length and short boards that can be used are $6\frac{1}{2}$ and $5\frac{1}{2}$. Furthermore, the number of clamps that might be used to make a bookshelf is 10 large clamps, $16\frac{8}{12}$ small clamps, and $36\frac{6}{4}$ screws. However, after knowing the many possible materials that can be used to make bookshelves, S1 has not been able to determine the maximum number of bookshelves that can be made from all available materials. Therefore, the researcher again provided defragmentation through scaffolding to stimulate S1 to round up the results of the distribution between the stock of materials and the number of materials needed to make 1 bookshelf. The results of S1 work can be seen in Figure 4.

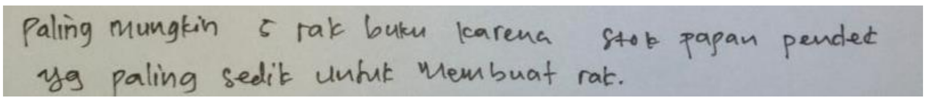


Figure 4. S1 Answer Snippet After the Third Defragmenting

From figure 4, it can be seen that after being given defragmentation, S1 can determine the maximum number of bookshelves that can be made from all available materials, which is 5. S1 also explains the logical reason, namely that there is the least stock of short boards, thus limiting it to making more than 5 bookshelves. Furthermore, at the stage of re-examining, there is accommodation to the thought process of S1. This is because S1 requires defragmenting through disequilibration to review the troubleshooting steps performed as a whole. Hamdani et al. (2021) define accommodation as a change in students' thinking schemes that occurs due to certain treatments, thus changing or creating new schemes. As for the defragmenting provided, it can stimulate S1 to check whether there are errors or inappropriate steps.

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b. Defragmenting S2 Thinking Structures in Solving Mathematical Problems on Pisa Model HOTS Questions

S2 is a subject that has low problem solving skills. S2 can describe the problem in a simpler way, but is not able to relate the problem to mathematical material to solve the problem. This is because the thinking structure of S2 does not match the problem. More details can be seen in the following image.

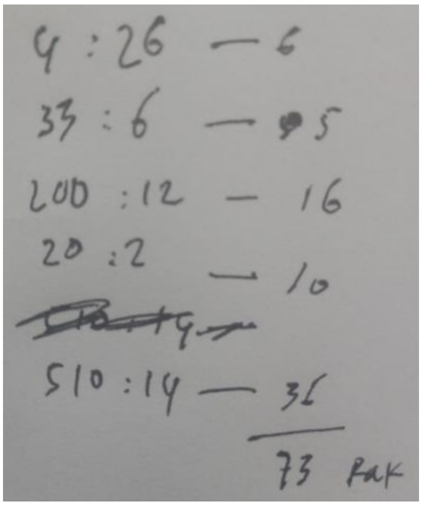

Figure 5. S2 Answers Before Defragmenting

Based on Figure 5, it can be seen that at the stage of understanding the problem, S2 is assimilated. S2 can directly describe the problem as being simpler but not optimally. Supiarmo (2021) states that when assimilation occurs, students do not change the schema, but adjust the new information to the existing schema. Through the results of interviews and supported by the results of think aloud, Masters without difficulty explained the materials needed to make 1 bookshelf, namely 4 long blackboards, 6 short wooden boards, 12 small clamps, 2 large tongs, and 14 screws. S2 can also describe the total available materials, namely 26 long whiteboards, 33 short wooden boards, 200 small clamps, 20 large clamps, and 510 screws. This proves that S2 is able to simplify problems by revealing important information even though they do not fully know the information asked for in the problem. In line with what was expressed by Halpern (2014), the stage of understanding the problem includes the ability to describe important elements related to information that is known and asked in the problem.

Furthermore, at the stage of developing the strategy, there is accommodation for the S2 thinking scheme. Accommodation occurs because S2 requires defragmenting to integrate mathematical concepts into the given problem. Supiarmo (2021) explains that accommodation occurs when students adapt to new experiences, so that it has an impact on the formation of new schemes or changing old schemes due to certain factors. Based on Figure 5, S2 only performs the division operation regarding the number of materials needed to make 1 bookshelf with all of the available materials. This shows that Master has not understood the information asked, so he does not know the right mathematical material to solve the problem. According to King (2019), the stage of developing a strategy is a step to interpreting procedures according to concepts that allow them to be applied to solve problems.

The researcher then defragmented the S2 thinking structure in order to recall the appropriate mathematical material used to solve the problem. The defragmenting carried out by the researcher is in the form of questions about how the master's knowledge is on linear programming material and how to solve linear programming problems. Through this feedback, S2 can recall concepts related to linear programming in determining the maximum value, so that it is possible to apply it to determine how many possible bookshelves can be made. So, after being given defragmenting, Masters can relate mathematical concepts to linear programming material to solve problems. This finding is in line with the theory of connection knitting (Subanji, 2015), which creates a link between the structure of thinking and so that students are able to develop strategies for the problems given. The following is a snippet of S2's answer after being given defragmentation to formulate a strategy.

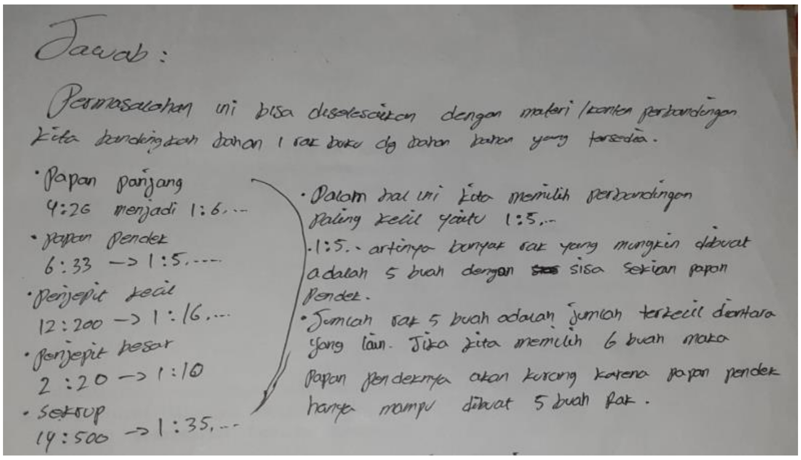

Figure 6. S2 Answer Pieces After the First and Second Defragmenting

Through Figure 6, it is known that in carrying out the master's plan, there is accommodation. This is because S2 requires defragmenting to determine the results of the comparison between the number of materials needed to make 1 bookshelf and the total stock of materials available. The initial step, S2 only did a comparison of 1:6 for the long board, 1:5 for the short board, 1:16 for the small clamp, 1:10 for the large clamp, and 1:35 for the screw. However, S2 has not been able to find the smallest comparison value of each of the many materials used to make 1 bookshelf for each type of stock material available. Therefore, the researcher conducted defragmentation by asking questions in the form of examples that raised cognitive conflicts related to the comparisons made by S2. After defragmenting, S2 can realize that the material to make a bookshelf that has the smallest comparison value is a short board, which is 1:5.

Furthermore, the researcher again carried out defragmentation through scaffolding on S2 to draw conclusions about the final solution found in solving the given problem. Then, after being given defragmentation, S2 was able to conclude that the maximum possible number of bookshelves that could be made is 5. The results of S2's work after defragmenting can be seen in Figure 7.

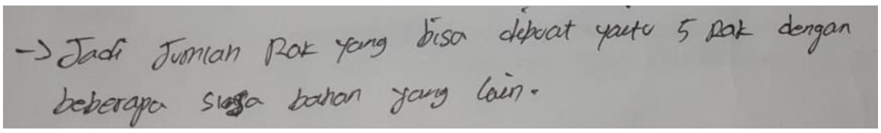

Figure 7. S2 Answer Snippet After the Third Defragmenting

As for the final stage, namely the step of re-examining S2, experiencing accommodation. This is because S2 requires defragmenting via disequilibration to check the previous troubleshooting steps thoroughly. According to Bormanaki (2017), accommodation is the transformation of students' thinking that occurs as a result of certain treatments, thereby changing or bringing up new schemes. Through defragmenting, researchers can stimulate S2 to re-examine whether there are errors or inappropriate steps.

Discussions

Based on the results, students with low problem solving abilities experienced changes in cognitive structure as a result of data exposure, with the same tendency in solving mathematical problems on the HOTS questions of the PISA model.The changes in the structure of thought through defragmentation are described as follows.

At the stage of understanding the problem, there is an assimilation of students' thinking processes. Assimilation occurs because the schema that students have is in accordance with the problem. Supiarmo (2021) said that when assimilation occurs, students do not change the scheme because the structure of the problem they find is in accordance with the available scheme. Students can describe the problem but not completely, but the information that is known and asked about the problem can be expressed through interviews.

Furthermore, at the stage of developing the strategy there is accommodation to the students' thinking schemes. This is because students need defragmenting to connect the right mathematical concepts with a given mathematical problem. Dorko (2019) states that accommodation is a cognitive structure adapted from new experiences, thus giving rise to new schemes or changing old schemes. Researchers defragmented students to recall knowledge related to mathematical concepts of linear programming material to build solutions to problems. This is in line with the theory of connection knitting (Subanji, 2015), which creates connections between thinking structures so that students can develop strategies.

At the stage of implementing the plan, students' cognitive processes experience accommodation. This is because students' cognitive schemes are not by the planned strategy, so defragmenting is needed to overcome them. Supiarmo (2021) states that accommodation is a cognitive structure that is adapted through new experiences as a result of the given stimulus. Students initially experienced an error in applying the formula, so the researcher provided defragmentation that could correct the error.

As for the final stage, namely re-examining, students' thinking schemes experience accommodation. This is because students need defragmenting to review the problem solving that is done as a whole. Dorko (2019) states that accommodation is a cognitive structure adapted from new experiences, thus giving rise to new schemes or changing old schemes. After being given a reflection, students can check the answer whether there are still errors, and the steps are not right.

CONCLUSION

Based on the results and discussion of changes in students' thinking schemes through defragmenting in solving mathematical problems on the PISA model HOTS questions, it can be concluded that students experience assimilation at the stage of understanding the problem. Assimilation occurs when students can directly simplify the problem, even though it is not completely. Furthermore, at the stage of formulating strategies, implementing plans and re-examining the thinking process of students, some students experience accommodation. This is because students need defragmenting to connect mathematical concepts to solve problems, correct errors, and complete incomplete problem solving steps.

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