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High School Students' Ability with Translation Among Mathematical Representations in Solving the HOTS-Based Problems

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Abstract: Translation is considered as a step in transforming the information contained from the source representation to the destination representation. In the process of students doing mathematical translation there are four stages of activity, Unpacking the Source, Preliminary Coordination, Constructing the Target, and Determining Equivalence. This study aims to analyze the activities carried out by students in translating representations from graphic to symbolic, table to symbolic, and verbal to symbolic based on HOTS. This research was conducted at SMA Lamongan Regency with three research students in class XI who had learned about the concept of quadratic functions. The instruments used were translation questions and interview guidelines. The applied data analysis focused on four stages of translation activity which were then grouped according to (high, medium, and low categories). The results showed that the translation of verbal representations into symbolic ones was the most difficult for students to complete.

Keywords: mathematical translation, representation, HOTS.

Abstrak: *Translasi dinilai sebagai langkah dalam mentransformasikan informasi yang termuat dari representasi sumber ke representasi tujuan. Kemampuan siswa dalam mentranslasi representasi sangat penting dalam pembelajaran. Proses siswa dalam melakukan translasi matematis terdapat empat tahapan aktivitas, Unpacking the Source (membongkar suatu masalah), Preliminary Coordination (menghubungkan suatu masalah), Constructing the Target (melakukan kontruksi target), dan Determining Equivalence (pengecekan kembali). Penelitian ini bertujuan untuk menganalisis proses aktivitas yang dilakukan siswa dalam melakukan translasi representasi dari grafik ke simbolik, tabel ke simbolik, dan verbal ke simbolik berbasis HOTS. Penelitian ini dilaksanakan di SMA Kabupaten Lamongan dengan tiga siswa penelitian kelas XI yang telah belajar mengenai konsep fungsi kuadrat. Instrumen yang digunakan adalah uji soal translasi dan pedoman wawancara. Analisis data yang diterapkan, difokuskan pada empat tahapan aktivitas translasi yang kemudian dikelompokkan sesuai dengan (kategori tinggi, sedang, dan rendah). Hasil penelitian menunjukkan translasi representasi verbal ke simbolik yang paling sulit diselesaikan oleh siswa.*

Kata kunci: *translasi matematika, representasi, keterampilan berpikir tingkat tinggi.*

▪ INTRODUCTION

Analyzing is part of the process of learning mathematics. This is in line with the explanation by Marzuki, et al. (2021) that at each level there are mathematical topics in the development of analysis, critical reasoning, problem solving, and communication skills. The learning strategy that can be used in analyzing a mathematical problem is through translation ability. Translation ability is one that influences the solution strategy for solving mathematical problems. As the opinion of Nurrahmawati, et al. (2021) that translation ability plays an important role in solving mathematical problems so that it influences solution strategies in problem solving. Meanwhile, according to Bossé,

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Michael and Chandler (2014), translation ability is defined as a cognitive ability to transform information contained in one form of representation (source) to another form of representation (target).

The ability of translation affects the solution strategy of solving mathematical problems through representation. In general, Moscovici (1988) states that representation is a configuration (shape) that can describe or represent something in another form. In line with this opinion, Caverly (2019) reveals the intent of the mathematical concepts developed by students in the learning process. An important role in representation was revealed by Ahmad, et al. (2020) that translation ability is a means of understanding concepts and thinking mathematically and expressing understanding of concepts. Meanwhile, according to Sa'Dijah, et al. (2020) simply states student representation as anything that students can make to show their work. In line with this opinion, Caverly (2019) revealed cognitive plans developed by students in the learning process. Based on some of these statements, representation is an embodiment that can describe mathematical ideas constructed in the human brain.

Representation is also one of the seven basic capabilities used in the PISA framework (OECD, 2016). Some researchers say that students have difficulty formulating representations in the form of mathematical models in solving PISA problems (Nurdin, 2013; Syafri, 2017; Aisyah & Madio, 2021; Purnomo, et al. 2021) Indonesia is ranked 69 out of 76 countries when viewed based on PISA results 2015 (OECD, 2016). Indonesia is ranked 45th out of 50 countries in the field of mathematics based on the results of Klieme's study (2016). It can be concluded that the results of PISA and TIMSS are still relatively low. By looking at these results, the role of the teacher as a teacher is needed to train students to be able to think and analyze at high representation. Teachers can introduce the use of representation to understand a concept and can connect several concepts by involving several representations (Hutagaol, 2013).

TIMSS and PISA have carried out international assessments of students' abilities in the fields of mathematics and science, namely the HOTS assessment (Susiswo, et al. 2021). HOTS is an important aspect in Education. HOTS has become the main focus of some people who care about education. As described by Purnomo, et al. (2021), that the main goal of educational institutions is to instill higher-order thinking skills (HOTS). The curriculum applied in Indonesia has also emphasized the importance of higher order thinking skills (High-Order Thingking Skill) students (Sadijah, et al. 2021).

In line with efforts to improve the quality of education, questions requiring students to have higher-order thinking skills are highly recommended to be presented in a lesson. HOTS questions are math problemsnon routine that contains elements of analyzing, evaluating, and creating. Rahmawatiningrum, et al. (2019) revealed that HOTS mathematics is highly recommended in various forms of class assessment (Ma'Rufi, et al. 2020; Widana, 2017). Based on information regarding the results of Klieme (2016), it is still necessary to improve the quality of education in Indonesia. Thus, one of the efforts to improve the quality of education in Indonesia, especially in the field of students' representational translation ability, has an effect on solving mathematical problems. The application of the translation of mathematical representations can be developed through HOTS, namely by increasing students' high-level thinking and communication patterns in solving mathematical problems. Solution to problem(problem solving) not only through the process of remembering or memorizing, but also required to make a relationship, categorize and provide conclusions on some of the mathematical problems that have been presented.

Several researchers have conducted research related to translation between representations. Bosse (2011) in his research found four activities in translating from graphic to symbolic. These activities areUnpacking the Source, Preliminary Coordination, Constructing the Target, andDetermining Equivalence. Bosse suggests that further research on the translation of mathematical representations other than graphical to symbolic is needed to complement his research to examine in more detail the translation process. Previous research by Bosse et al. (2011) stated that the translation of verbal representations into tables, symbolic, graphics, and the translation of table, symbolic, graphic representations into verbal is the most difficult translation.

The researcher conducted preliminary research by continuing the previous research to examine the translation process of graphic representations into symbolic, table into symbolic, and verbal into symbolic. Students determine equations symbolically to obtain graphical components. Then, based on the similarities and patterns of the relationship between the two variables symbolically, students construct it to symbolic (Bosse, 2011). Based on the opinion of Subanji & Nusantara (2013) states that in constructing graphs besides being carried out by examining formulas (equations) it can also be done by connecting changes in two variables directly, so that by connecting changes in two variables directly, so researchers suspect that there is a process of translating graphical representations into symbolic, tabular to symbolic, and verbal to symbolic directly without going through other representation intermediaries. In this study, the quadratic function was chosen as the material concept to be studied, because the quadratic function can be expressed in various forms and students are required to be able to translate it. Based on these considerations, the researchers determined the quadratic function as material for conducting a more in-depth study related to students' mathematical translation abilities in solving HOTS-based problems.

▪ METHOD

This research was conducted using a qualitative approach. This is in accordance with the opinion of Nugrahani (2014) that qualitative research is a method for exploring meaning that comes from social problems. This qualitative research process involves many assignments, such as asking questions and procedures for collecting data, summarizing and analyzing data as well as explaining data.

The type of research used is descriptive exploratory research, because researchers naturally hope to be able to obtain in-depth and detailed data about the processes experienced by students when translating representations of the concept of a quadratic function. The researcher also completes the information by studying the processes students go through in translating mathematics. Through qualitative methods, all oral and written facts obtained from observed sources and other related documents are described as they are, then reviewed and presented as briefly as possible to answer research questions.

The research was carried out from October 22 2022 to November 19 2022 with students in class XI MIPA 3 and XI MIPA 4 at SMA Kabupaten Lamongan as subjects. At the time of licensing, researchers were given the opportunity to make offline observations on September 19 which was recommended by the research assistant teacher. Each class found as many as 30-35 names of children per class. This is based on the recommendation of the teacher accompanying the researcher. This observation is intended to consider students' communication skills. Based on these considerations, the researcher determined that the research subjects were T1 students from the high group, S1 subjects from the medium group, and R1 subjects from the low group.

Before the research was carried out, the researcher prepared a HOTS-based test instrument related to the translation of representations adapted from the research of Bosse, et al. (2014) namely by analyzing the translation process through 4 stages, Unpacking the Source, Preliminary Coordination, Constructing the Target and Determining Equivalence. The questions on the sheet consist of 3 questions, namely: translation from graphic to symbolic, table to symbolic, and verbal to symbolic. In addition to the test questions, the complementary instrument used by the researcher is semi-structured interviews so as not to limit the results of the subject's answers. The questions and interviews presented have been reviewed by experts from UM Mathematics lecturers. After the preparation and revision process, the validation results of the test instrument validation of the translation process of representation by the validator were declared valid instruments and could be used for research.

In the student translation process test results stage, the data obtained is qualitative data from the results of the translation process test for each subject. The subject's answers were analyzed using the framework of the translation stages activities that the researcher had prepared well. While at the stage of the results of interviews with students, the data obtained is qualitative which comes from the results of interviews conducted by researchers with students on several test questions given. This data is used to support information about the translation process carried out by students. The object of the study consisted of 3 students based on the grouping of students' translation processes, so that they were divided into 3 categories, namely 1 student in the low group, 1 student in the medium group and 1 student in the high group. If students can correctly change the information in the source representation into the target representation, that is through the student's translation process correctly. The translation process is passed through 4 stages, Unpacking the Source, Preliminary Coordination, Constructing the Target and Determining Equivalence. (Bosse et al. 2014)

The HOTS-based test item test indicators used by researchers are, in terms of translation representation from graphic to symbolic, table to symbolic, and verbal to symbolic, namely students are able to complete the 4 stages of translation activity which has been adapted from the research of Bosse et al. (2014). Following Table 1 shows an explanation of the indicators in the selection of research subjects and Table 2 is a test of translation of representations on the subject.

Table 1. Test Indicators of Representational Translation on Subjects

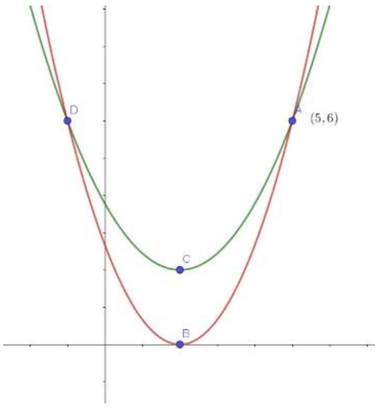
Activities	Translation among Representation	Description
Understanding problems	Unpacking the Source	• Mention known information on the problem • Mention what is asked in the problem
Planning the solution	Preliminary Coordination	• Determine the initial step

of a problem		of establishing the target representation
Implement the solution of a problem	Constructing the Target	• Form a target representation to solve the problem
Crosscheck	Determining Equivalence	• Checks whether the target representation matches the initial representation

Table 2. Representational Translation Question Test on Subjects

Soal 1

Diberikan gambar grafik fungsi seperti berikut.



Gambar 1. Grafik Fungsi

Diketahui terdapat banyak grafik fungsi kuadrat yang melewati titik (5,6) dan memiliki titik puncak (2,b) tergantung pada nilai b. Namun, semua grafik tersebut pasti melewati titik yang sama, selain (5,6). Tentukan nilai titik tersebut!

Soal 2

Berikut ini diberikan tabel yang menyatakan hubungan antara banyak kotak hadiah (x) yang dapat dibuat dari lembaran karton dan biaya yang diperlukan untuk membuatnya P(x)

x	***P(x) (dalam Rupiah)***
60	*720.000*
70	*735.000*
90	*675.000*

Analisis dan jelaskan nilai fungsi kuadrat yang menyatakan hubungan antarabanyak kotak hadiah (x) dan biaya yang diperlukan untuk membuatnya P(x)!

Soal 3

Sebuah jembatan dengan permukaan jalan yang rata memiliki tiang kembar yang berdiri tegak setinggi 75 meter di atas permukaan jalan dan terpisah sejauh 400 meter. Untuk menambah keamanan dan memperindah jembatan, dipasang kawat pembatas yang menggantung dari ujung atas tiang ke ujung atas tiang lainnya sehingga membentuk parabola. Kawat pembatas menyentuh permukaan jalan tepat di tengah jembatan. ***Bagaimana cara menyimpulkan fungsi kuadrat yang dapat mengilustrasikan kawat pembatas jembatan tersebut!***

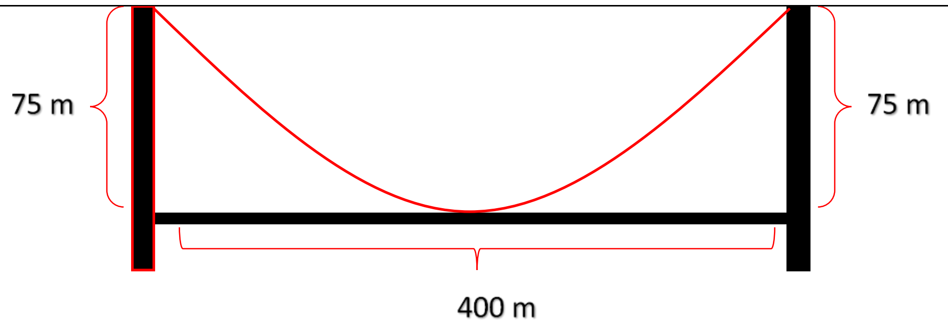


Figure 2. Twin Pillar Bridge

▪ RESULT AND DISSCUSSION

In this study, 51 data from class XI students at Lamongan District High School worked on 3 questions prepared by the researcher. Through the data that has been collected, as many as 78.85% of students have difficulty translating students' mathematical representations from graphic to symbolic in quadratic function material. This is evidenced by the existence of errors in interpretation and implementation by students. translating the representation from graphic to symbolic, this is because there are several stages that are incomplete which causes implementation errors when constructing targets. And 17.31% of students who can only take advantage of their ability to translate representations from graphic to symbolic. In this case, the researcher decided to present the results of the preliminary study to one of the 78.85% students who were classified as experiencing difficulties in translating mathematical representations in quadratic function material. Meanwhile, through the results of the translation percentage from table to symbolic representation, it was obtained 3.85% of students who succeeded in completely completing the questions given. The other 96.15% do not meet the requirements to carry out the process of translating representations from tables to symbolic ones. For verbal to symbolic representations, 1.92% of students were able to complete the questions well, 3.85% of students stopped at the target construction process, and 94.23% of students failed to complete the questions properly and completely.

Subject Translation Process from Graphic to Symbolic

Information disclosure process (Unpacking the Source) on the translation from graphic to symbolic varies in each group. High group subjects tend to be able to analyze and disassemble various information from the representations presented and identify other components even though they are not written down explicitly. The group is only identifying information in the form of available points. Meanwhile, the low group was less able to identify one additional component. On activityUnpacking the Source one of the low group subjects made a mistake and identified the given point. Errors made by this low group of subjects are included in misinterpretation (Adu-Gyamfi, et al. 2012). Misinterpretation is an error that appears in stating the attributes or properties contained in the representation of the source or target. However, the identification error made by Subject R1 was not used in the next process.

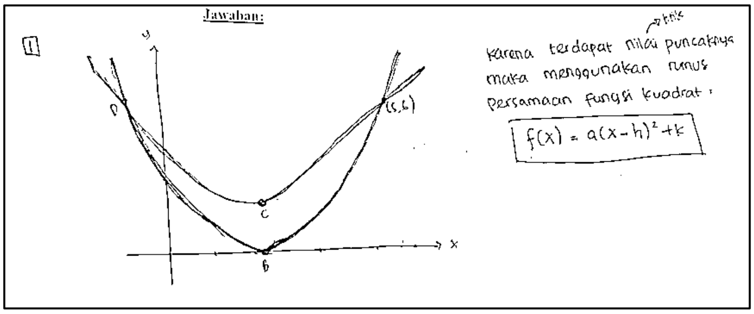


Figure 3. Unpacking the Source in the Graphic to Symbolic of Subject T1

In addition to the disclosure of information presented by the graphs, Unpacking the Source activity also determined by the formation of ideas used to form the target framework. This activity is indicated by the subject's analysis of whether or not the information that has been identified so far is sufficient or not. By recognizing the understanding of information, the subject is able to determine the ideas that will be used to form a quadratic function. Based on the results of the interviews, almost all subjects stated that all the information they had understood was sufficient to form a quadratic function. This is contrary to the results of the work shown by the subjects in the middle and low time Constructing the Target. When the construction process is stopped, the subject cannot analyze that the cause of the discontinuation of the process is lack of information identified unless the subject is in the low group. The medium group subject then immediately switched to using the trial and error technique from the results of the understanding he had obtained through the information obtained.

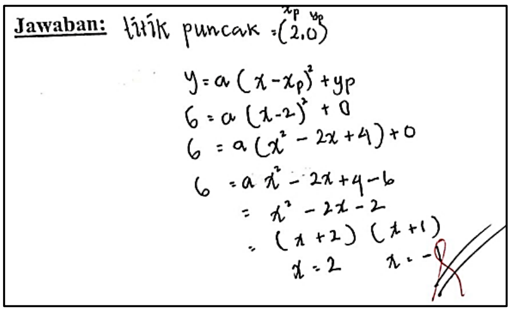


Figure 4. Constructing the Target on the Graphic to Symbolic of Subjects S1

Next, the subject performs the Preliminary Coordination activity which is shown by the activity of connecting the information that is owned with the target being constructed. In this activity the subject develops a target framework from the basic ideas that have been formed in the previous activity by considering the information that has been collected and the concepts that have been understood before. High group subjects show good ability in forming basic constructions based on the information they have. This is because the subjects in the high group are able to link the information they have with previously understood concepts. Although not through an easier substitution step. Subject T1 also uses a good alternative step by shifting the graph to make it easier to work on.

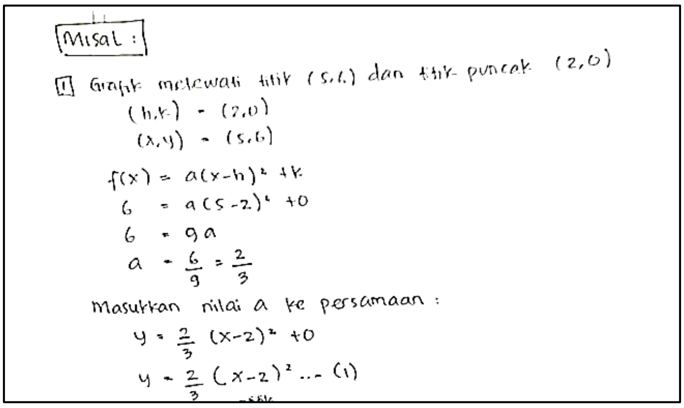


Figure 5. Preliminary Coordination on Graphic to Symbolic of Subject T1

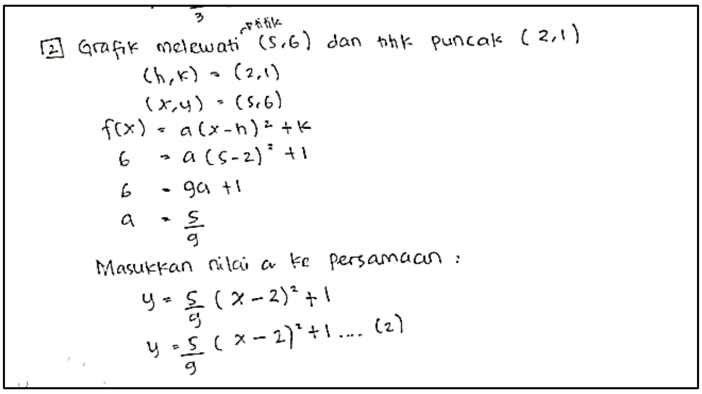


Figure 6. Preliminary Coordination on Graphic to Symbolic of Subject T1

While the subject group is showing an error in interpretation in determining the general form of the quadratic function. Subject S1 made the mistake of writing the general form of the less-than-perfect quadratic function, ie f(x) = (x-x1) (x-x2). Interpretation errors made by the S1 subject were possible because the subject only memorized the quadratic function without understanding the meaning of each symbol. The subject does not understand the meaning f(x) = y. The results of the work shown by the S1 subject showed that the subject did not understand the concept of a quadratic function properly.

Determining Equivalence activity almost all show the same result, that is, the subject uses back substitution with the coordination point passed by the graph. Subjects in the high group from T1 who have formed the correct quadratic function simply check by performing one-point substitution to ensure the suitability of the quadratic function with the graph. While the subject uses trial and error in substituting the two points to determine the suitability of the function because the function to be guessed must fulfill both points. Thus, Determining Equivalence activity in the medium group and low group subjects it was not carried out along with the Constructing the Target activity. The following are the results of the work of the subjects in the high, medium and low groups.

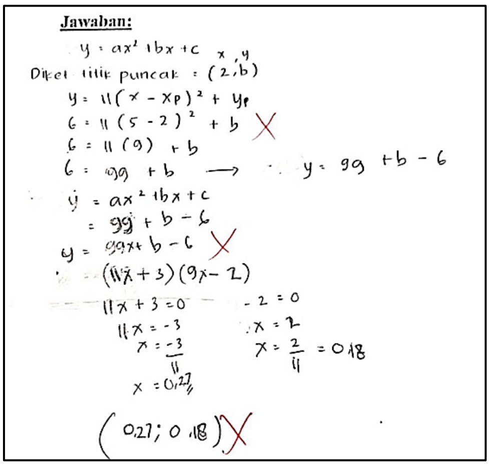


Figure 7. Constructing the Target from Graphic to the Symbolic of Subject R1

Subject Translation Process from Table to Symbolic

In the translation from table to symbolic, translation begins by analyzing the relationship between columns in the table, where P(x) is a function that states the price to be paid to create gift box. All research subjects carry out Unpacking the Source activities by analyzing the relationship between these columns, and only subjects from the low group who do not understand the meaning of the relationship from P(x) and x. The process of disclosing information on the translation from tabular to symbolic does not show much difference in the high and medium groups. The two groups quite well understood the information contained in the table, and understood the data relationships between columns x and columns P(x). This shows that subject R1 made a misinterpretation by misunderstanding the meaning contained in the table representation (Adu-Gyamfi, et al. 2012).

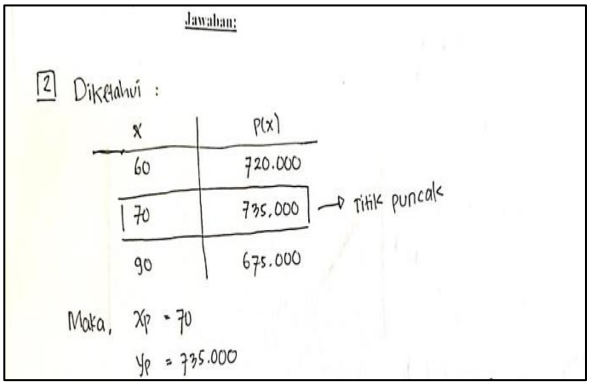


Figure 8. Unpacking the Source from Table to Higher Symbols

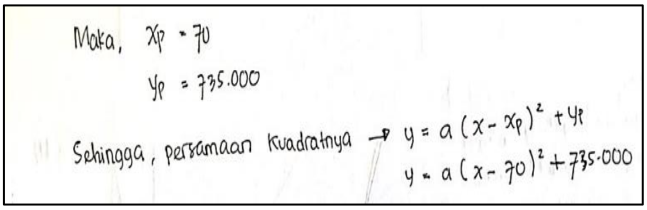


Figure 9. Preliminary Coordination from Table to Symbolic

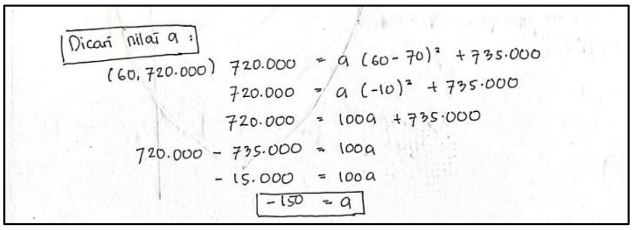


Figure 10. Constructing the Target from Table to Symbols

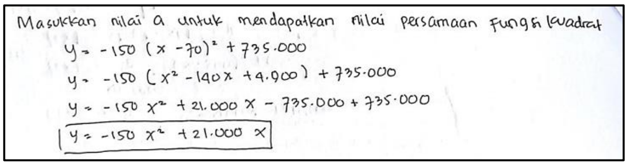


Figure 11. Determining Equivalence from Tables to Symbols

Unpacking the Source Activity is also determined by the subject's performance in entering the table as a coordinate point. All subjects except subjects S1 and R1 were able to enter tables as coordinating points with partners(x, P(x)). Ndlovu & Ndlovu (2020) mention this stage as "fitting that is adjustment. In this study, the formation of the target framework is shown by selecting the general form of the quadratic function. The following are the results of the work of the subjects in the high, medium and low groups.

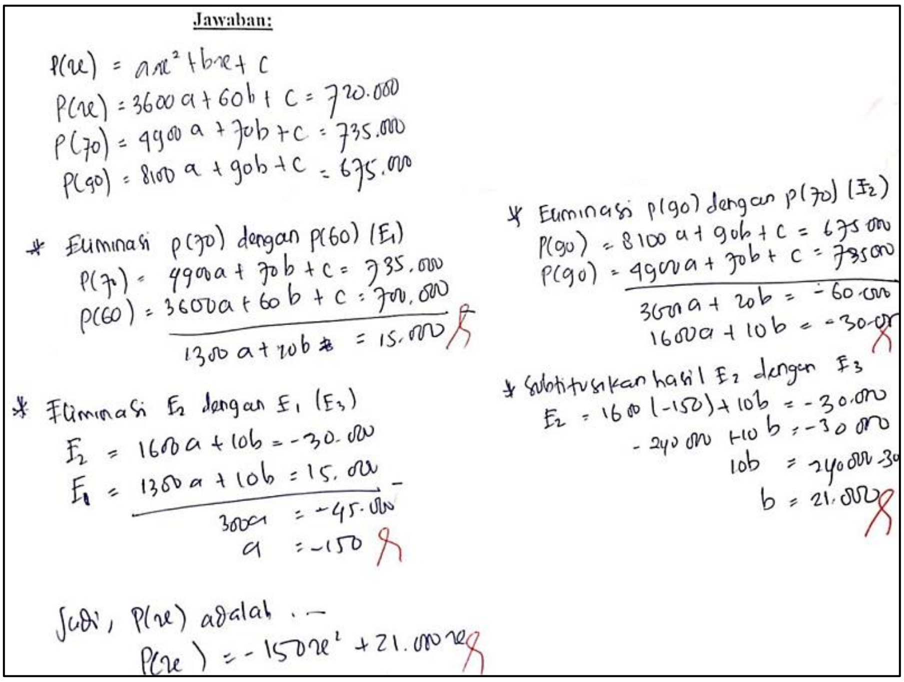


Figure 12. Students' Activity from Table to Symbolic Translation of Subject S1

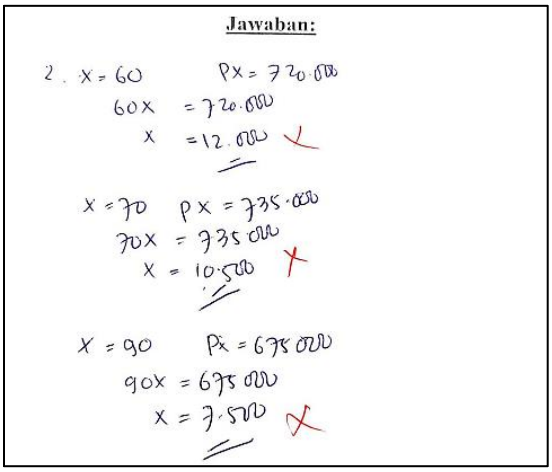


Figure 13. Students' Activity from Table to Symbolic Translation of Subject R1

Subject Translation Process from Verbal to Symbolic

In translation from verbal to symbolic, translation begins by making a sketch based on verbal information on the source representation. By understanding all the information presented in the verbal information presented, all subjects carried out the Unpacking the Source activity quite well.

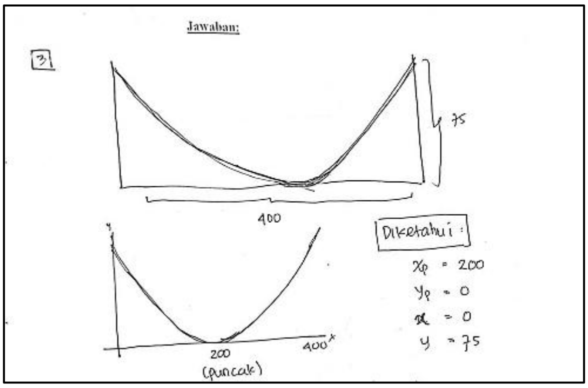


Figure 14. Unpacking the Verbal Source to the Symbolic Level

Furthermore, the subject performs the Preliminary Coordination activity by fitting the graph sketch to the coordinate plane. Stylianou (2011) mentions this activity as "curve fitting" where the subject puts the appropriate point on the graph to the coordinate field to then adjust it to the formula (function). In general, the medium and low group subjects were not able to properly link the sketch to the coordinate plane except for subject S1. The high group subjects made several different placements on the coordinate plane, but all of these placements were correct and could form a suitable quadratic function if constructed properly.

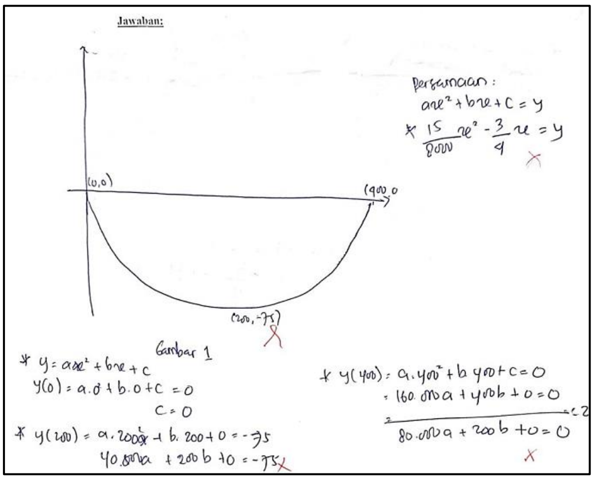


Figure 15. Unpacking the Source and Preliminary Coordination from Verbal to Symbolic of Subject S1

In the process of constructing targets, only high group subjects showed Constructing the Target activity which is good enough. Determining Equivalence activities the transition from verbal to symbolic was almost not carried out by subjects from the medium and low groups. The following are the results of the work of the subjects in the high, medium and low groups.

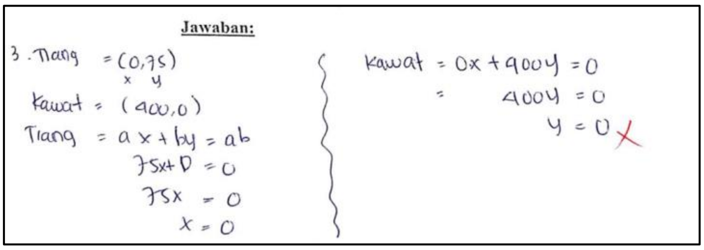


Figure 16. Students' Activity from Verbal to Symbolic Translation of Subject R1

▪ CONCLUSION

Based on the general form of the quadratic function that is widely used by the subject to express the quadratic function in symbolic form is f(x) = ax2 + bx + c. Only high group subjects are able to name alternative symbolic representations of quadratic functions that can be used and adjust the necessary information to use them, just like the quadratic function formula f(x) = a(x-xp) + and p. Meanwhile, the medium and low groups tend to use only one representation. Based on the results of the research, the researcher suggests to readers or further research to be able to develop research on the translation process of students' mathematical representations in solving quadratic function problems as teaching materials through the scaffolding method.

The results of this study also show that the translation from graphic to symbolic is the easiest to analyze and try to construct by the subject. Although some subjects demonstrated a trial and error step in the construction process, all subjects understood the source and target well. The translation from tabular to symbolic also cannot be constructed perfectly by the medium group, while the low group cannot understand properly related to source representation. Translation from verbal to symbolic is the least understood and constructed by the medium and low groups. Even though all groups have made transitional representations in the form of graphic sketches, the subjects of the medium and low groups still have difficulty constructing targets from verbal representations. The findings of this study also support the results of research conducted by Adu-Gyamfi et al. (2012) which presents the order of translation performance performed by the subject.

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