High School Students’ Responses in Solving Linear Program Problems Based on SOLO Taxonomy Viewed from Mathematical Disposition

L F Claudia\(^1,\) a, T A Kusmayadi\(^2,\) b, and L Fitriana\(^3,\) c

\(^1,\)\(^3\) Department of Mathematics Education, Faculty of Teacher Training and Education, Sebelas Maret University

\(^2\) Department of Mathematics, Faculty of Mathematics and Natural Science, Sebelas Maret University

Jalan Ir. Sutami 36A Keningan Jebres, Surakarta, Indonesia 57126

\(^a\)lidya.fransisca23@gmail.com, \(^b\)tri.atmojo.kusmayadi@gmail.com, \(^c\)lailafitriana_fkip@staff.uns.ac.id

ABSTRACT. In mathematics learning, students need a cognitive domain that is supported by an equivalent affective domain. One of the factors students can master or like math is that they must have an interest and curiosity in learning mathematics. Interest of students can solve mathematics problems more efficiently. The combination of affinity and interest in learning mathematics will form a positive attitude which is often called a mathematical disposition. Mathematical disposition is students' beliefs and attitudes about mathematics that support the tendency to see mathematics as reasonable and useful as well as the role he or she believes diligence plays in solving mathematical tasks. SOLO taxonomy can be classified into five levels ranging from simple to high levels, pre-structural, uni-structural, multi-structural, relational, and extended abstract. This study uses descriptive qualitative research that has the purpose of describing level response of students who have high, medium, and low mathematical disposition categories. The subjects in this study were senior high school students in the City of Kediri with a purposive sampling technique in a class of 35 students and obtained three subjects which represent every category of mathematical disposition. The results of this study are (1) Student with high mathematical disposition is at the extended abstract level, (2) Student with medium mathematical disposition is at the multi-structural level, (3) Student with low mathematical disposition is at the pre-structural level.

1. Introduction

Mathematics learning requires an assessment, in assessment is the process of gathering and applying information for the achievement of learning outcomes. In solving a mathematical problem or a problem encountered in everyday life. Surely each individual has its way to solve it, it allows the differences in abilities possessed by each individual. Similarly, students who have different abilities in the field of mathematics, problem solving is using or transferring existing knowledge and skills to answer an unanswered questions or difficult situations [1]. Mathematics is the science of numbers, the relationship between numbers, and operational procedures used in solving problems about numbers. One branch of mathematics is algebra, where algebra is a part of mathematics where alphabet and other common symbols are used to represent numbers and amount in formulas and equations. In learning algebra there are algebraic standards that must be implemented by students proposed by...
NCTM: (1) understand patterns, relationships, and functions; (2) represent and analyze situations and structures using Mathematical algebraic symbols; (3) apply mathematical modelling to substitute and rule a concepts in quantitative terms; (4) changes in analysis in various ways [2].

Students' ability to solve problems can be seen from students' responses when dealing with mathematical problems. A teacher cannot directly see the ability of students in solving problems but can know that ability from the quality of the responses given. Existence of SOLO taxonomy to classify the level of students' ability to solve mathematical problems. Students who can solve mathematical problems well, not only their abilities but also their interests and curiosity. The SOLO taxonomy be discovered by Biggs and Collis in 1982, and the SOLO taxonomy was designed as an instrument for evaluating the quality of students' responses to problem solving tasks and classifying into five levels ranging from simple to high levels: (1) pre-structural, (2) uni- structural, (3) multi-structural, (4) relational, and (5) extended abstract [3]. SOLO taxonomy can help to describe effort the level of complexity of understanding students' concepts of the subject, through five levels and is stated to be applicable to all subjects [4].

Sometimes, the mistakes of students is in understanding a concept, such as research conducted by Agustin which is studied using the SOLO taxonomy level, students' conceptual understanding is in the low category and the percentage is 54% [5]. The SOLO taxonomy level of high ability students can reach the extended abstract level. The mistakes of highly capable students are not careful in substituting and inaccurate in reading questions. The SOLO taxonomy level of medium ability students can reach the relational level. The mistake of student is the calculation operations in solving problems. The SOLO taxonomy level of students with low ability can reach the multi structural level. The mistake of low ability students is lack of understanding of questions and understanding of triangle subjects [6]. SOLO taxonomy organizes a framework for classifying the quality of responses that can be inferred from the response structure to a stimulus [7]. There are two main features of the SOLO taxonomy: (1) Thinking mode: iconic, concrete-symbolic, formal; (2) Levels of response: the levels of prestructural, uni structural, multi structural, relational, and the last is extended abstract [8]. The criteria for classifying five levels can be seen in Table 1 [9].

| No. | SOLO Taxonomy's Level | Description |
|-----|-----------------------|-------------|
| 1   | Pre-structural         | Students do not use the information provided to solve problems, do not understand the questions given even work on things that have nothing to do with the problem. |
| 2   | Uni- structural        | Students use the information provided, but have not been able to get the correct answer. |
| 3   | Multi- structural      | Students use some of the information provided separately and students solve problems only in certain cases so that they still don’t get the right answer. |
| 4   | Relational             | Students can understand all the statements given and connect these statements to get the right answer, but he did not find new principles even have the wrong concept and students can not apply these statements to other cases. |
| 5   | Extended Abstract      | Students can use all the information provided to solve problems, students connect between information to get the right answers and students find new principles and can prove their truth. |

Table 1 shows the level of students’ responses in solving mathematics problems based on SOLO taxonomy. That level, students can find out how the process of using information obtained in the problem can then be used to solve mathematics problems. SOLO taxonomy is generally used to enhance and determine students’ cognitive abilities in solving mathematics problems.

Solving mathematics problems is perfecting a problem that must be solved related to numbers. According to Pehkonen problem-solving tasks usually involve non-standard problems in which the
solver does not instantly know the solution or the correct solving strategy [10]. NCTM also argued: (1) in the application of mathematics, the role of problem solving is to provide a framework, (2) giving mathematical problems directly can make students to be strengthen and enhance insight into what they know, (3) and can excite students’ mathematics learning [11]. In learning mathematics, solving problems is a routine activity that must be done. Because it can help students apply information obtained from the teacher, and can develop the cognitive domain of students.

Learning mathematics is not only in the cognitive domain, but also the affective domain is needed, as stated in the learning objectives of mathematics in schools, that are to live and practice honest behavior, discipline, responsibility, care (mutual cooperation, cooperation, tolerance, peace), polite, responsive and in socializing we are required to be able to show a positive attitude. The combination of affinity and interest in learning mathematics will form a positive attitude which is often called a mathematical disposition. Katz defines disposition as an inclination to behave cognizantly, oftenly and friendly to achieve specific purpose [12]. Students use metaphors to express their dislike of mathematics. For example: Like chitlin, mathematics is a purchase taste most people, including myself, find disgusting and unpleasant. I hate Chitlin, I hate math [13]. It is the affective domain of attitudes and beliefs that help shape students’ reactions to mathematics and therefore represent key elements in developing students’ mathematical dispositions [14].

Role of affective domains on students' abilities, positive mathematical dispositions: in the process students must have attitudes, behavior, motivation, interests, and a sense of achievement in learning mathematics [15]. Examining students' self-concepts of ability in mathematics and gaining perspectives on protection that improve concepts about them in mathematics can support positive changes in attitudes towards mathematics and support mathematics [14]. Mathematical disposition has the most significant influence on students' problem solving abilities through the application of LKPD-assisted PBL learning models on social arithmetic material compared to IQ [16]. The important of mathematical disposition in existing research has a positive effect on students. In this study, want to show mathematical disposition of students with three categories: mathematical disposition high, medium and low.

Productive mathematical disposition is defined as: (someone’s) beliefs and attitudes about mathematics supporting the inclination to see mathematics as reasonable, useful, and worthwhile [17]. Mathematical disposition deals with how students solve mathematical problems; whether they are confident, diligent, interested, and flexible thinking to explore various alternative solutions to problems [18]. Mathematical disposition indicators proposed by NCTM in Standard 10 make several indicators regarding mathematical disposition, including [19]: (1) Self-Confidence in using mathematics, solving problems, communicating ideas, and giving reasons, (2) Flexibility in exploring mathematical ideas and attempting to find alternative methods for solving problems, (3) Persevering working on math assignments, (4) Interest, curiosity, and encountering ability in doing mathematical tasks, (5) Tend to monitor and reflect on their own performance and reasoning, (6) Assess the purpose of mathematics to other situations in other sectors and everyday experiences, and (7) Appreciation of the role of mathematics in the culture and value of mathematics, as a tool and language. Mathematical disposition: where self-confidence, interests, and regards mathematics as something positive. Students will be easier to accept and learn mathematics because if every student has a positive attitude towards something, it will be waged in learning something. Likewise with solving mathematical problems, if students have a positive attitude towards mathematics, these students will be at the highest level in the SOLO taxonomy.

2. Methods
This study uses descriptive qualitative research in which researchers will reveal, describe and spell out the ways of thinking, ideas, opinions, attitudes and other behaviors of research subjects that are observed carefully. Theory in qualitative tradition means looking for concept, ideas or opinions written by experts in books, journals, etc. [20]. The subjects used in this study were students of 11th grade at Senior High School 8 in Kediri City. Taking one class as a population, where the class has
already been recommended by the mathematics teacher. In the class there are 35 students, with a sampling technique is purposive sampling. The instruments in this study used two instruments, the first instrument was a test item about a linear program which was then used to analyze students’ responses at the SOLO taxonomy’s level. One class selected was given a questionnaire in the form of a mathematical disposition questionnaire, given questions about the linear program and conducting unstructured interviews where used interview guidelines, could be adjusted to students’ answers. After finding data that is felt in accordance with certain considerations of the researcher and the class is heterogeneous, the subject chosen in each category are high mathematical disposition, medium mathematical disposition, and low mathematical disposition.

3. Result and Discussion

The instrument of mathematical disposition questionnaire is the first instrument given to students. From provide a questionnaire to a one class consisting of 35 students, there students will be chosen in one population. Classification from mathematical disposition: (1) student in the high mathematical disposition category, (2) student in the medium mathematical disposition category, and (3) student in the low mathematical disposition category. The following is the distribution of students’ mathematical disposition shown in Table 2.

| Mathematical Disposition Category | Number of Students |
|----------------------------------|-------------------|
| High                             | 9                 |
| Medium                           | 15                |
| Low                              | 11                |
| Total students                   | 35                |

From the three categories of mathematical disposition, 3 subjects were chosen to represent that category. Here is an analysis of students’ responses to the SOLO taxonomy:

3.1 Students with high mathematical disposition categories (HMD)

![Figure 1. Photograph of HMD subject’s answers in solving problem](image)
Result from HMD Interview:

P : What exactly is the corner point??
HMD : I forgot the name, Miss. Anyway, the lines that meet continue to be the point.
P : What's the biggest profit formula? it's you directly away.
HMD : Because the biggest profit, so I think the maximum value divided by the largest fund. Right or not, Miss?
P : Yes, that’s right, but you don’t write the formula.

(R = researcher, HMD = High mathematical disposition)

Then in Figure 1 and result from HMD Interview, HMD students can transform story questions into the answer because HMD can already use the information available in the questions. Using symbols as examples $x$ as shrimp crackers and $y$ as fish crackers, HMD can model mathematics correctly. HMD can simplify from the equation function to be very simple, and then HMD can understand the steps / procedures that are then carried out to finding the values of $x$ and $y$ using the elimination system.

HMD can draw the graph correctly, but in writing what should be the intersection point, HMD writes the corner point. Knowing which points will be traversed by the graph, HMD is right in finding the area of the settlement set and is also correct in using the symbol $\leq$ because of the principle of the linear program, if the equation is known $\leq$ then the right line must be shaded and vice versa. The equality of target functions, HMD can substitute correctly that it finds its maximum value. Then HMD can also apply the formula to find the biggest profit in percent ($\%$), by using the formula that has been obtained. HMD uses information appropriately, can model mathematics, doing linear program problem solving very procedurally, that it can find the biggest profit in percent ($\%$) correctly and write conclusions. In the interview, HMD also gave the same answer to what he was doing.

The result of HMD’s answer, it can be seen that students in the category of high mathematical disposition (HMD) on the category of students’ responses in the SOLO taxonomy is at the level of extend abstract because HMD can use information very well. The level of extend abstract if students can apply data / information into concepts and processes and then provide temporary results to connect with other processes, students can draw relevant conclusions and be responsible for the results received [21]. Students can find information and can form ideas and connect with concepts through reflection and evaluation [9]. Students can use ideas or information then apply concepts to the process of solving problems and then provide results, they can also use other ideas or information in a second way and they can find relevant conclusions, they can make ideas from the results received [22].

3.2 Students with medium mathematical disposition categories (MMD)
Result from MMD Interview:

R : \( x + y = 2.500.000 \) What’s that equation?

MMD : Shrimp crackers plus fish crackers, the same as the mother issued her fund 2.500.000 in everyday.

R : But when you write the mathematical model, why is that possible \( 50.000x + 75.000y \leq 2.500.000 \)?

MMD : I read the question again, and then I just enter the fund for the crackers.

R : Actually, do you understand whether or not you do the mathematical modeling?

MMD : Knowing Miss. Maybe when I write on the example, I forget (laughing).

R : More thoroughly please.

MMD : I forget, Miss. Actually, there are \( x \) and \( y \).

R : How do you find the points?

MMD : This is how I do it, if \( x = 0 \) then what is the value of \( y \).

R : Is it true that the point you are looking for?
MMD : I counted it that, Miss.
R : And then, which is the maximum point?
MMD : I forget with that formula.
(R = researcher, MMD = medium mathematical disposition)

Then in Figure 2 and result from MMD Interview, MMD students in changing story questions into what is known in the questions with an example. That way MMD can understand what information is in the problem. MMD is appropriate in using symbols to represent what is known in the problem by using the variable $x$ as shrimp crackers and the variable $y$ as fish crackers, but MMD writes the equation $x + y = 2,500,000$ which when seen in the problem is not the right equation. Modeling the mathematics MMD can write the correct equation, but it is still not right in writing the facts of the linear program, $x \geq 0; y \geq 0$. MMD is still not appropriate in writing the facts possessed by linear programs. MMD can simplify the known equation into the simplest equation, MMD writes for equation (1). Furthermore, MMD takes steps to look for values of $x$ and $y$ using the elimination method, after getting the values of $x$ and $y$ MMD looks for anywhere the point to be drawn on the graph. In determining which points MMD is not right because the concept used is still not right, it is shown in MMD work that gets a point $(0; 2.5)$. That’s the graph that was drawn became less precise. Even to find the biggest profit in percent (%), MMD is not appropriate in applying concepts or formulas that were obtained previously and then MMD clearly answers incorrectly and does not provide conclusions from the answers obtained. Even through interviews, MMD was not yet right in processing the available information.

The result of MMD’s answer, it can be seen that students in the category of medium mathematical disposition (MMD) in the students’ responses category in the SOLO taxonomy is at the multi structural level, because MMD is not appropriate in using existing information. Even MMD does not understand the facts of linear program, the steps used by MMD in finding answers are actually structured / procedural, MMD is not quite right in finding points to be drawn on the graph. The formula for finding the biggest profit in percent (%) of MMD is also not precise and does not write a conclusion, the answers obtained are still not right yet. The multi structural level if students have understood several components, however this is still separate from one another so they have not formed a comprehensive understanding, some simple connections have been formed [23]. Students have not been able to connect the basic concepts with existing information [9]. Students apply the available information but cannot connect that information and then in draw a conclusion is not relevant [21].
3.3 Students with low mathematical disposition categories (LMD)

![Graphical representation of LMD subject's answers](image)

**Figure 3.** Photograph of LMD subject’s answers in solving problems

Result from LMD Interview:

P : How do you the mathematics modelling?
LMD : I don’t know, Miss. Anyway, that's what was in the problem I wrote back on the answer sheet. It already represents what is known in the problem.
P : But there must be algebraic similarities because there are two variables that you use.
LMD : I forgot why.
P : Continue to answer that how it means? suddenly 50.000.000 ? Too much? in that question, like that ?
LMD : That’s too much zero, Miss. I want to write Idr 50.000,00.
P : Try to explain the answer part? I feel something is wrong.
LMD : Search \(x\) and \(y\). That process is \(50.000 \times 40 = 2,000,000\) that’s per 30% per kilogram.
P : What? Where is the formula from? How can you get it like that?
Using what formula if you want to find the values of \(x\) and \(y\)?
LMD : Elimination method.

(R = researcher, LMD = Low mathematical disposition)
Then in Figure 3 and result from LMD Interview, LMD students in changing the information contained in the story into the answer sheet using symbols with the use of variable $x$ as shrimp crackers and variable $y$ as fish crackers. The LMD in the answer sheet is clear that in processing the information obtained is not quite right, it can be seen when LMD modeling the mathematics. LMD does not know or do not understand how to model the mathematics using equations. Seen from the process of solving the problem, in general LMD does not understand the concept of a linear program, which starts from what is known, modeling the mathematics until the procedure is not appropriate. Based on the answers and interviews LMD has not been able to process the information contained in the questions and has not been able to relate the existing concepts. Then LMD get results that are clearly not right. In general LMD has not been able to hold the concepts of mathematical modeling.

The result of LMD’s answer, it can be seen that students in the category of low mathematical disposition (LMD) in the students’ responses category in the SOLO taxonomy is at the pre structural level, because LMD has not been able to use information properly and has no meaning or concept. LMD tends not to provide answers to question given. The pre structural level: (1) students write irrelevant conclusions due to incorrect use of data or information, (2) students only have half the information and have no relationship, so they cannot produce a concept and doesn’t have meaning, and (3) students can not solve problems correctly because they do not have the skills [21]. Students don't do on problems, they used that information is not interconnected, they not knowing what was asked about the problem, irrelevant conclusions, write the same as the questions on the answer sheet [9].

### 4. Conclusion

Based on data obtained from test and interview questions, it can be analyzed the level of students’ responses in the SOLO taxonomy based on students’ mathematical disposition categories. The results of this study are a student with a high mathematical disposition category at the level of extended abstract, a student with a medium mathematical disposition category is at a multi-structural level, and then student with a low mathematical disposition category is at the pre-structural level.

The implication of this research is the relationship between mathematical disposition and the level of students’ responses in the solo taxonomy, we know if the level of students’ responses in solving mathematics problems is varies. The affective domain of mathematical disposition that can know students’ interests and curiosity in learning mathematics. The interest in learning mathematics, students will be easier and more interested in learning mathematics. In receiving and applying information received by students can make it easy to teachers for assessment. Responses level in SOLO taxonomy can help teachers to know students’ understanding in receiving a lesson, how students utilize and apply the information obtained. Mathematical disposition is the affective domain of students' interests and curiosity can be explored by motivating students to interesting in mathematics. Every student has a positive attitude towards something, it will be waged in learning something. Likewise with solving mathematical problems, if students have a positive attitude towards mathematics, these students will be at the highest level in the SOLO taxonomy.

Based on the results that have been analyzed it appears that students with low mathematical disposition will be more difficult in solving mathematical problems that make the student get in the pre-structural level of SOLO taxonomy, student with medium mathematical disposition will understand a little bit of the information available and can apply in solving mathematical problems that make the student get in the multi-structural level of SOLO taxonomy, and student with a high mathematical disposition will easily understand the information available and can apply in solving mathematical problems that make the student get in the extend abstract level of SOLO taxonomy. These results prove that there is a need for affective domains to implanted in students, students are more motivated and have an interest in learning mathematics. Interest is the main key that students must have in order to receive mathematics lessons well. The purpose of learning is not to accumulate facts, however the ability to use basic knowledge to infer or explain various phenomena, that students benefit from the little knowledge that they remember and understand.
Acknowledgements
The authors thanks to Sebelas Maret University in Surakarta for allowing doing this research. Also say thanks to Senior High School 8 in Kediri City that supported us during data collection, so we can accomplish this research.

References
[1] J. E. Ormrod, “Educational Psychology: Developing Learners, 8th Edition”, University of Northern Colorado, 2014.
[2] NCTM, “Principles and Standards for School Mathematics”, United States of America: The National Council of Teachers of Mathematics, Inc., 2000.
[3] J. B. Biggs, and K. F. Collis, “Evaluating the Quality of Learning: The Structure of The Observed Learning Outcome (SOLO) Taxonomy”, New York: Academic Press, 1982.
[4] G. M. Boulton-Lewis, “The SOLO Taxonomy as a Means of Shaping and Assessing Learning in Higher Education”, Higher Education Research & Development, vol. 14, no. 2, 143-154, 1995.
[5] S. A. Agustin, “Pemahaman Konseptual Siswa Dikaji dari Taksonomi SOLO dalam Materi Fungsi Eksponensial di SMA”, Scientific Publications: Universitas Tanjungpura Pontianak, 2019.
[6] C. C. Chan , M. S. Tsui , M. Y. C. Chan, and J. H. Hong, “Applying the Structure of the Observed Learning Outcomes (SOLO) Taxonomy on Student's Learning Outcomes: An empirical study”, Assessment & Evaluation in Higher Education, vol. 27, no. 6, pp. 511-527, 2002.
[7] L. H. Lian and W. T. Yew, “Assessing Algebraic Solving Ability: A Theoretical Framework”, International Education Studies, vol. 5, no. 6, pp. 177-188, 2012.
[8] J. Pegg and D. Tall, “The Fundamental Cycle Of Concept Construction Underlying Various Theoretical Frameworks”, ZDM Mathematics Education, vol. 37, no. 6, pp. 468-475, 2005.
[9] J. C. Caniglia and M. Meadows, “An Application of The Solo Taxonomy to Classify Strategies Used by Pre-Service Teachers to Solve “One Question Problems”, Australian Journal of Teacher Education, vol. 43, no. 9, pp. 75-89, 2018.
[10] A. Kojo, A. Laine and L. Averi, “How Did You Solve It? Teachers’ Approaches to Guiding Mathematics Problem Solving”, LUMAT General Issue, vol. 6, no. 1, pp. 22-40, 2018.
[11] E. Ortiz, “The Problem-Solving Process in a Mathematics Classroom”, Florida: NSUWorks, vol. 1, no. 1, pp. 4-13, 2016.
[12] L. M. Clark, J. N. DePiper, T. J. Frank, M. Nishio, P. F. Campbell, T. M. Smith, M. J. Griffin, A. H. Rust, D. L. Conant, and Y. Choi, “Teacher Characteristics Associated With Mathematics Teachers' Beliefs and Awareness of Their Students' Mathematical Dispositions”, Journal for Research in Mathematics Education, Vol. 45, No. 2, pp. 246-284, 2014.
[13] J. Cai, V. Robison, J. Moyer, N. Wang, and B. Nie, “Mathematical Dispositions and Student Learning: A Metaphorical Analysis”, Annual Meeting of the American Educational Research Association, vol. 4, no. 1, 2012.
[14] K. L. Hall, “The Mathematical Disposition Of Middle School Students: An Examination Of Students’ Self-Concept Of Ability In Mathematics”, All Theses And Dissertations, p 67, 2016.
[15] E. D. Minarti and Wahyudin, “Conceptual understanding and mathematical disposition of college student through Concrete-Representational-Abstract approach (CRA)”, J. Phys.: Conf. Ser. vol. 1157, no. 042124, 2019.
[16] H. Karsim, Suyitno and Isnarto, “Influence of IQ and Mathematical Disposition Toward the Problem Solving Ability of Learners Grade VII Through PBL Learning Model with the Assistance LKPD”, UJME, vol. 6, no. 3, 2017.
[17] C. A. Feldhaus, “How Pre Service Elementary School Teachers’ Mathematical Dispositions are Influenced by School Mathematics”, Am. Int. J. Contemp. Res., vol. 4, no. 6, pp. 91-97, 2014.
[18] L. G. Katz, “Disposition as Educational Goals”, ED363454, 1993.
[19] National Council of Teacher of Mathematics (NCTM), “Curriculum and Evaluation Standards
for School Mathematics”, Reston, VA: Authur, 1989.

[20] J. R. Raco, “Metode Penelitian Kualitatif”, Jakarta: Grasindo, 2010.

[21] H. Chick, “Cognition in the Formal Modes: Research Mathematics and the SOLO Taxonomy”, Math. Educ. Res. J., vol. 10, no. 2, pp. 4-26, 1998.

[22] R. Ekawati, I. Junaedi, and S. E. Nugroho, S E 2013 “Study of Students’ Responses in Solving Mathematical Problem Solving Problems Based on SOLO Taxonomy”, Unnes Journal of Mathematics Education Research, p 101-107, 2013.

[23] A. P. Exacta, I. Sujadi, and S. Subanti, “Students’ Responses to Mathematics Education at Veteran Bangun Nusantara University in Solving Logic Problems Based on SOLO Taxonomy”. Electronic Journal of Mathematics Learning. ISSN: 2339-1685. Vol. 3, no. 10, 2015.