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Profile of Student Algebraic Thinking with Polya's Problem-Solving Strategy: Study on Male Students with Field Independent Cognitive Style

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ABSTRACT

This study aims to describe the profile of students' algebraic thinking with Polya's problem solving strategy in completing a linear program conducted on male students with field independent cognitive style. This research is exploratory research with qualitative approaches. In accordance with the purpose of the study, the subject (single subject) were male student with field independent cognitive style. Single subject were screened from 119 participants (male students in grade X) at a high school in the city of Mataram, Indonesia. The criteria for determining a single subject are male students with field independent cognitive style, and having the highest math scores on linear algebra material. The research instrument consisted of the main instrument (researcher/human instrument) which interacted directly with the subject to explore the subject's algebraic thinking profile, and research aid instruments consisting of the GEFT test, mathematical ability test, linear programming tasks, and interview guidelines. Through Polya's problem solving, the students' algebraic thinking profile has been described, where the subject has represented mathematical ideas using algebraic expressions, the subject interprets algebraic expressions; the subject uses symbolic representations, formulations, and expressions of equations using algebraic conventions; and the subject can interpret the solution.

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A. INTRODUCTION

During the last three decades, reforms in the field of mathematics education and teaching have continued (Niss et al., 2016), along with the development of Science, Technology, Engineering and Mathematics (STEM), and Mathematics is considered the "Queen of Knowledge" because almost all fields science is supported by mathematics (Evendi & Verawati, 2021). However, the achievement of mathematics teaching competence to date has become a major challenge (MacDonald, 2020). On the one hand, many students at the secondary school education level do not realize the importance of mathematics and its relevance to their work careers and their future education (Gijsbers et al., 2020). Previous studies found difficulties in teaching mathematics among students with low cognitive levels, because in the previous learning routine the teacher did not apply cognitive strategies effectively (Pendlington, 2005). Finally, updates on many aspects of mathematics teaching, especially those oriented to basic needs in mathematical concepts, need to be investigated more intensively (Boesen et al., 2014).

One of the concepts of mathematics that is highly emphasized at all levels of education is algebra (Chimoni & Pitta-Pantazi, 2017). The realization of the need for algebra teaching is mainly based on the fact that algebra is related to the development, formation and communication of knowledge in all field or matter of mathematics (Midgett & Eddins, 2001). In addition, algebraic thinking has an important role in solving mathematical problems (Sukmawati et al., 2018). Early intervention in a well-planned way of learning and identifying the student's way of thinking becomes a key element for initiating algebraic thinking, through this naturally increasing the translation of pure arithmetic situations into the symbolic language characteristics of algebraic thinking (Adamuz-Povedano et al., 2021). Therefore, an extensive study in mathematics was carried out to investigate algebraic concepts in elementary and middle school students, specifically focusing on the context of algebraic thinking (Cai & Knuth, 2011).

Previous studies have shown that algebraic thinking can develop starting in elementary and middle school age children by conducting an explicit approach (Pinnock, 2021), with a supportive learning environment (Radford, 2008). Algebraic thinking can also develop with the use of various forms of reasoning (Pedemonte, 2008). Algebraic thinking performance has also been investigated which is associated with various cognitive factors, such as information processing (Fuchs et al., 2012). Several recent studies have explored the process of algebraic thinking through Polya's problem-solving steps (Muniroh et al., 2017; Nu, 2019). The problem-solving steps according to Polya (1945) are to understand the problem, develop a settlement plan, carry out a settlement plan, and re-examine the solution. Ways of solving problems and students' thinking can be assessed through Polya's problem-solving steps (Faulkner et al., 2021). Although there are many studies or research on algebraic thinking, it is acknowledged by Chimoni & Pitta-Pantazi (2017) that studies on how individuals use their cognition in algebraic thinking seem to need further exploration. In accordance with the research agenda of the National Council of Teachers of Mathematics (NCTM) which emphasizes future research for identification the mathematical concepts and cognitive reasoning processes that facilitate algebraic thinking (Danişman & Erginer, 2017).

Algebraic thinking is a way of thinking that involves mathematical thinking skills (generalization, abstraction, analytical thinking, dynamic thinking, modelling, and organization) which is very useful in solving mathematical problems, other fields of science, as well as problems in everyday life (Lew, 2004). The indicators of algebraic thinking according to NCTM are understanding the patterns, relationships, and functions of mathematic; the use of algebraic symbols to represent and analyze mathematical situations and structures; use mathematical models to represent and understand quantitative relationships; and analyzing change in various contexts (Midgett & Eddins, 2001). Hardiani et al. (2018) explores the opinions of several mathematicians about algebraic thinking, and suggests algebraic thinking as a thinking process that involves the representation of mathematical ideas including coefficients, constants, formulas, functions, variables using algebraic expressions, and interpreting the solutions.

In Indonesia, algebraic thinking in the mathematics learning curriculum at the elementary and secondary school levels is still implicit, so it is necessary to develop a comprehensive teaching design to make it easier for students to develop algebraic thinking (Pratiwi et al., 2019). Before this is realized (the development of mathematics teaching design is carried out), then as a foundation, information about the profile of algebraic thinking is needed for students. This profile is a prototype for developing mathematics learning designs to train students' algebraic thinking. On the one hand, the results of previous studies show that algebraic thinking performance is related to individual cognitive regulation in information processing (Fuchs et al., 2012). Moving on from Bandura (1982) theory of self-efficacy, we believe that each student's information processing is different, depending on their cognitive style. There is a strong relationship between self-efficacy and students' algebraic thinking skills, where students with high self-efficacy tend to have good algebraic thinking skills, and vice versa (Kurniawan & Mashuri, 2021). Studies in relation to cognitive style, the algebraic representations affiliated with students' cognitive styles (Nisak et al., 2020). Previous studies have shown that cognitive style is related to student acceptance of information processing (George et al., 2018), and information processing plays a role in individual acceptance of information and behavior (Armstrong et al., 2012).

Cognitive style is identified with the level of individual consistency in how to understand, organize, and process information (Rayner & Cools, 2011), and is believed to affect individual performance (Armstrong et al., 2012). In the aspect of cognitive regulation, cognitive style plays a role in mediating individual cognitive abilities in learning and receiving information (Viator et al., 2020). Individual cognitive styles are categorized into field dependent and field independent (Witkin, 1967; Witkin et al., 1977). Algebraic thinking has been investigated in relation to students' cognitive styles (Hardiani et al., 2018; Nisak et al., 2020). A previous study by Hardiani et al. (2018) has examined the algebraic thinking of female students with field independent cognitive style, the study results show three main results from the narrative questions presented; students are able to represent algebraic ideas by manipulating symbols and variables, building mathematical models that represent algebraic ideas, and interpreting solutions. As a comparison, a study needs to be conducted to explore the algebraic thinking of male students with field independent cognitive style. This study aims to describe the profile of students' algebraic thinking with Polya's problem solving strategy in completing a linear program conducted on male students with field independent cognitive style.

B. METHODS

This research is exploratory research with qualitative approaches, specifically aims to describe the profile of algebraic thinking in male students with field independent cognitive style in completing linear programs. Participants in the study were 119 male students in grade X in a senior high school in the city of Mataram, Indonesia. The age range of the participants was 15-16 years, with 51 (43%) male and 68 (57%) female students. The research instrument consisted of the main instrument and research auxiliary instruments. The main instrument is the researcher (human instrument) who interacts directly with the subject to explore the profile of the subject's algebraic thinking. The research aid instruments consist of 4 (four) instruments, namely; GEFT test (Group Embedded Figure Test), math ability test, linear programming task, and interview guide.

The research subjects were male students who met the criteria; a) field independent cognitive style (measured and determined by the GEFT instrument), and b) has the highest math score on linear algebra material (measured by the mathematical ability test instrument conducted on all participants). Based on these criteria, it was found that the research subject with GEFT results, mathematical ability score (MAS), and subject code as presented in Table 1. The research subject was only 1 student (initial ZW) considering that based on the criteria, the maximum score was achieved by ZW with a MAS score of 76. As shown in Table 1.

Table 1. Research subject criteria

Initial	**MAS**	**Cognitive style (GEFT)**		**Gender**	**Subjek code**
		Score	**Category**		
ZW	76	17	*field independent*	Male	SIL (Subjek-*Independent*-Male)

Linear program task is given to the research subject. Narrative of linear program tasks as follows.

"PUJI" Flower Shop, sells 2 kinds of hand bouquets, cheap but interesting. The first set consisted of 4 roses, 2 dahlias, and 3 tulips, while the second set consisted of 2 roses, 3 dahlias, and 1 tulip. The florist currently only has 48 roses, 36 dahlias and 33 tulips in stock. If the profit in the first series is Rp. 15,000, - and the profit in the second series is Rp. 12,000, - then do the following calculation.

1. *Create a mathematical model based on the data!*
2. *Draw a graph along with the solution area according to the mathematical model created!*
3. *From the graph, how many first and second series can be made so that the florist gets the maximum profit?*

Interviews on research subjects were conducted using an interview guide instrument which contained a collection of questions posed by researchers to research subjects. Interview guides are needed to reveal a picture of the subject's algebraic thinking. The interview transcript code for the subject used the SILSM code (SIL Math Problems/Linear Program Tasks), and for the researchers used the PSM code (Researcher). Completion of linear programming tasks follows Polya's (1945) problem-solving steps, namely understanding the problem (P1), compiling a settlement plan (P2), implementing the completion plan (P3), and re-examining the solution (P4). Indicators of algebraic thinking measured on the subject are representing mathematical ideas using algebraic expressions (A1); interpret coefficients, variables, and constants in algebraic expressions (A2); use the symbolic representations using algebraic agreement (A3); solution interpretation (A4). The data from the research were then tabulated and described to obtain the algebraic thinking profile of the subject (SIL) in solving mathematical problems based on Polya's problem solving steps.

C. RESULT AND DISCUSSION

The data presented are the results of interviews and subject observations (SIL) in completing linear programming tasks based on Polya's problem-solving steps. Interview transcripts were reduced by researchers, examples of interview excerpts as presented in Figure 1 to Figure 4 according to Polya's problem-solving steps. Excerpts of the results of interviews and observations of researchers on Subject 1 (SILSM1) is presented in Figure 1, it is related to understanding the problem.

In the transcript of the conversation (interview) with the subject, the researcher noted that there were at least 50 conversational scripts that explored how the subject understood the problem. Based on Figure 1 to understand the problem, first SIL mentions all the important elements that are known from the problem using their own sentences by making a table. SIL writes x, 4x, 2x, 3x, y, 2y, 3y, and so on until z = 15,000x + 12,000y [SILSM1005] [SILSM1007]. SIL constructs the z equation of the gain of the first and second circuits as the objective function [SILSM1021] [SILSM1022]. SIL mentions that there are 3 questions in SM1 using their own sentences [SILSM1023].

After reading the questions, SIL understands the meaning of the questions by restating everything that is known on the questions using their own sentences. SIL explained in detail all the important information contained in the questions, for example, based on the question there were 2 flower arrangements, the first series consisted of 4 roses, 2 dahlias, and 3 tulips while in the second series there were 2 roses, 3 dahlias and 1 tulip. Each flower has a stock, for which 48 roses, 36 dahlias, and also 33 tulips. SIL formulates an objective function by formulating a linear equation Z to find the maximum profit from the sale of 2 flower arrangements marked by writing z = 15000x + 12000y.

Based on Figure 1, SIL writes down the important elements to express algebraic expressions on questions that have been read with the help of tables because according to SIL, making tables will make it easier to solve problems. In conclusion, SIL finds important elements based on the problems presented and makes simple algebraic equation expressions, in this case SIL shows P1A1 algebraic thinking indicators. In addition, based on the algebraic expressions that have been raised, SIL interprets the understanding and compatibility between coefficients, variables, and constants in algebraic expressions (P1A2), as shown in Figure 1.

Label		Interview and Observation Activities
PSM1001	:	*In this first meeting, I ask you to read the questions first (Subjects are given time to read math problems 1)*
SILSM1001	:	*Yes, (the subject reads the math problem 1 given carefully from beginning to end while writing down the important information in the problem)*
PSM1002	:	*(After the allotted time is enough to read the math problem 1) Have you finished reading the problem?*
SILSM1002	:	*Yes, it's done.*
PSM1003	:	*Have you ever worked on a similar problem like this before?*
SILSM1003	:	*Never, but have worked on different questions on linear programming material given by the teacher in class.*
PSM1004	:	*Do you understand the meaning of this question?*
SILSM1004	:	*Yes, I understand.*
PSM1005	:	*What do you understand?*
SILSM1005	:	*Mmm…. (using his own language while rereading SM1) it is known that the question consists of 2 flower arrangements, the first flower arrangement and the second flower arrangement. Each set consists of roses, dahlias, tulips and maximum profit. Then… each flower has a stock. Here I will give an example. Well…I have to create a table.*
PSM1006	:	*Why should you create a table?*
SILSM1006	:	*To make it easier.*
PSM1007	:	*After creating the table, what will be written?*
SILSM1007	:	*So, let's say that in the first series it is x and the second series is y, hmmm, so in the first series it consists of 4 roses, 2 dahlias, and 3 tulips, while in the second series there are 2 roses, 3 dahlias and 1 tulip, this is for example in this first flower arrangement 4x, 2x, 3x, while the second set of 2y, 3y equals y. Here mmm…there is stock, so here is the hmm… minimum here.. there is a minimum limit for roses 48, the stock is 48, so I wrote it smaller than 48, and dahlia flowers are also smaller than 36, and so also tulips, smaller than 33. (as in Fig. 1)*

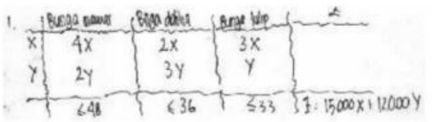

Fig.1

Label		Interview and Observation Activities
PSM1008	:	*Do you understand what you wrote? (pointing to Fig.1).*
SILSM1008	:	*Yes, I understand.*
PSM1009	:	*Do you also understand the written symbols? (while pointing back to Fig. 1)*
SILSM1009	:	*Yes*
PSM1010	:	*Ok, now why do you assume the first series to be x, and the second set to y?*
SILSM1010	:	*Because it's easier here because it's question b, asking for Cartesian coordinates makes it possible to answer them more easily.*
PSM1011	:	*Then, what is it called if there is x and y, the term is still do you remember?*
SILSM1011	:	*What is it…. hmm… the name is.. (while thinking back).*
PSM1012	:	*Maybe another name.*
SILSM1012	:	*(while remembering) Oh, that's a variable.*
PSM1013	:	*Do you know what variables mean?*
SILSM1013	:	*As far as I know, a variable is a number whose value is unknown.*
PSM1014	:	*Oh, I see.*
SILSM1014	:	*It seems like that.*
PSM1015	:	*For example 4x or 2y, what is the name?*
SILSM1015	:	*It's called a coefficient.*
PSM1016	:	*So what does the coefficient mean?*
SILSM1016	:	*Mmmm…..the coefficient is …mmm…a number that has a variable.*
PSM1017	:	*Then what is the meaning of 4x and 2y?*
SILSM1017	:	*4 is the number of roses, x the first set. 2 is the number of roses, y the second set.*
PSM1018	:	*What about the 2x and 3y? (pointing to the third column in Fig. 1).*
SILSM1018	:	*2x means the number of dahlias is 2, and x is the first set. As for 3y.. this….mmmm…same, 3 the number of dahlias for the second set of y.*
PSM1019	:	*As for the 3x and y (pointing to the fourth column in the table) what do they mean?*
SILSM1019	:	*Same, this means for 3 tulips in the first series, namely x, and 1 tulip for the second series, namely y.*
PSM1020	:	*So, what is in the last line (pointing to ≤ 48, ≤ 36, ≤ 33) what does it mean?*
SILSM1020	:	*Mmmm….(while reading again SM1) because the seller only has 48 stocks for roses, meaning there is a minimum limit, I use the sign ≤ which is smaller than 48. Likewise, the stock of dahlias and tulips, I write smaller than ≤ 36 and ≤ 33*
PSM1021	:	*Then, what else?*
SILSM1021	:	*Here ma'am, there is a profit for the first set of 15,000x and 12,000y profit for the second series. So I make the equation z. (as in Fig. 1)*

Figure 1. Excerpts from the researcher's interview with subject 1 (SILSM1) at the phase of understanding the problem

Excerpts from interviews and observations of researchers on Subject 1 (SILSM1) at the stage of making a settlement plan are presented in Figure 2. At this stage (see Fig. 2), SIL said it would create a mathematical model in the form of inequalities to solve the first question based on the algebraic expressions [SILSM1024] [SILSM1025] [SILSM1026]. Based on these data, it can be concluded, SIL reveals a plan of steps to solve the problem starting from the idea of making a mathematical model in the form of inequality expressions based on algebraic expressions made in the table (P2A1). SIL said it would describe the solution area of the inequality on a Cartesian coordinate graph to answer the second question [SILSM1028], as shown in Figure 2.

Label		*Interview and Observation Activities*
PSM1024	:	*You said earlier that there are 3 questions in this matter. How do you think you will solve these three questions?*
SILSM1024	:	*For the first question I created a mathematical model from the table I had created.*
PSM1025	:	*What kind of mathematical model?*
SILSM1025	:	*Inequality.*
PSM1026	:	*How do you create inequalities?*
SILSM1026	:	*The trick is to look at the column ..emm..each flower in the table (while showing the table in Fig. 1). The second column is for roses, the third column is for dahlias, and the fourth column is for tulips.*
PSM1027	:	*Are there other models besides inequality?*
SILSM1027	:	*No.*
PSM1028	:	*What about the other two questions?*
SILSM1028	:	*Next to the second question, I describe the solution area of the inequality on the Cartesian coordinate graph and finally find the maximum profit.*
PSM1029	:	*In your opinion, is there any other way?*
SILSM1029	:	*there is not other way.*

Figure 2. Excerpts from the researcher's interview with subject 1 (SILSM1) at the phase of the make a settlement plan

Based on the idea of making a mathematical model in the form of inequalities, SIL depicts the solution area on the graph (Cartesian coordinates). Based on the graph of the settlement area, SIL already has a prediction (a value that can be found) as a solution to answer the next question (P2A4). SIL said it would calculate the maximum profit to answer the third question [SILSM1028]. Based on the settlement area, the intersection points will be searched to calculate the maximum profit. Using the function equation, SIL will calculate the maximum profit (P2A3).

Furthermore, excerpts from the results of interviews of researchers on Subject 1 (SILSM1) at the stage of implementing the completion plan are presented in Figure 3. The transcript of the conversation (interview) between the researcher and the subject at this phase was about 102 scripts. To answer the first question, SIL creates 3 inequalities for each flower, using the addition operation marked by writing $4x + 2y = 48$ for roses, $2x + 3y = 36$ for dahlias, and for tulips $3x + y = 33$ [SILSM1032] [SILSM1033] [SILSM1034] [SILSM1035] [SILSM1036]. SIL creates three inequalities based on the table that has been created. That is, SIL creates a suitable mathematical expression (inequality) to answer the question (P3A1). Expression of the answer to the second question, that of the three inequalities made, SIL assumes the variables $x = 0$ and $y = 0$ and performs substitutions on the inequalities and operates them to find the value of each axis. This shows that SIL interprets a variable in an inequality if one of them is made equal to 0 then the value of the other variable will be obtained by converting it to an equation first, and besides that, by assuming it is equal to 0, SIL interprets it has something to do with describing a point on the xy-axis (P3A2), as shown in Figure 3.

Label		Interview and Observation Activities
PSM1030	:	Ok, looks like you already understand this problem and know how to answer these three questions. Do you want to try to solve this problem?
SILSM1030	:	Oh sure, I'll try.
PSM1031	:	Please. (researcher gives time to SIL to answer questions)
SILSM1031	:	(After approximately 45 minutes, SIL finished answering the questions and given the answer to the researcher). The following is the result of SIL's answer.

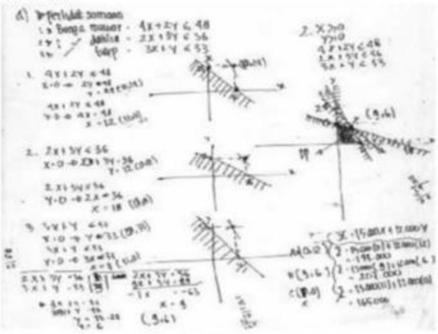

Fig. 2

Label		Interview and Observation Activities
PSM1032	:	Just now you have finished this problem, can you tell me again what you have been doing?
SILSM1032	:	For the first question, I created an inequality (created as shown below)

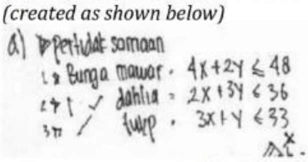

Fig. 3

Label		Interview and Observation Activities
PSM1033	:	How many kinds of inequalities have been created?
SILSM1033	:	There are three.
PSM1034	:	What are the inequalities?
SILSM1034	:	The first, $4x + 2y \leq 48$ for roses, the second $2x + 3y \leq 36$ for dahlias, and the last $3x + y \leq 33$ for tulips (pointing to Fig. 3)
PSM1035	:	What operation do you use on this inequality? (while pointing to the three inequalities in Fig. 3)
SILSM1035	:	Addition
PSM1036	:	Why do you add up $4x + 2y$, or $2x + 3y$, and $3x + y$? The table does not write the number sign
SILSM1036	:	Hmmm... (while looking back at the questions that have been read) because the information in the questions sells 2 flower arrangements, so the first series is added to the second series.
PSM1037	:	After you create the inequality, what is the next step?
SILSM1037	:	Mmm...now answer question b, by first finding the solution area for each inequality.
PSM1038	:	How do you find the solution area?
SILSM1038	:	Determined, ... by... mmm... for example, a rose $4x + 2y$ is smaller than 48, I suppose one of these variables is equal to 0... let's say mmm... $x = 0$, so $2y = 48$, $y = 24$, so (0.24), the second is the same, but the variable y is made 0, so $4x = 48$, and $x = 12$, we get (12,0). (pointing to Fig. 4)

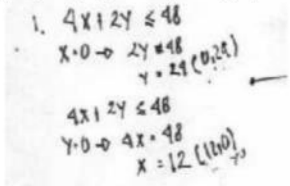

Fig. 4

Label		Interview and Observation Activities
PSM1039	:	Why do you suppose $x = 0$?
SILSM1039	:	Well, this is to find a point that passes through the x-axis, so that I assume x is 0.
PSM1040	:	Why do you suppose $y = 0$?
SILSM1040	:	This is also to find a point that passes through the y-axis, so that y is equal to 0.
PSM1041	:	Why when you suppose $x = 0$, the inequality $4x + 2y \leq 48$ turns into $2y = 48$?
SILSM1041	:	I substitute 0 into 4x, so $4 \times 0 = 0$, so it becomes $2y = 48$
PSM1042	:	Why does the sign change to '=' (equal to)?
SILSM1042	:	So that we can find the value of y.
PSM1043	:	Ooh, I see.
SILSM1043	:	Yes.

Figure 3. Excerpts from the researcher's interview with subject 1 (SILSM1) at the stage of carry out the settlement plan

After assuming the variables x = 0 and y = 0 in each inequality, the step taken by SIL is to change the inequality by the substitution process, for example for the first equation to be 2y = 48, we get y = 24, then the point becomes 0.24, and so on for equation other. At this stage, SIL uses number operations to obtain the value of x and value of y according to the applicable algebraic law so that a pair of points is obtained that can help answer the next question (P3A3). In the substitution process, finally found the value of the function z. In the end, SIL means traders get a maximum profit of 207,000 from the maximum point of the series. In conclusion, SIL explains the final solution obtained as a solution to the problem according to the context (P3A4). The last phase is re-checking the solution. Excerpts from interviews and observations of researchers on Subject 1 (SILSM1) at this stage are presented in Figure 4.

Label		***Interview and Observation Activities***
PSM1082	:	*After all the questions are answered. I invite you to re-check the answer?*
SILSM1082	:	*(SIL looks at the question, then SIL matches what is written in Fig. 1) judging from the problem, this is correct.*
PSM1083	:	*What is correct?*
SILSM1083	:	*The inequality that I have made.*
PSM1084	:	*(based on the researcher's observations) Why is that being examined?*
SILSM1084	:	*To make sure it's right with the problem.*
PSM1085	:	*Is there anything else to check?*
SILSM1085	:	*Hmmmm........(SIL checks every step that has been done until the maximum point is obtained) is this also correct?*
PSM1086	:	*What do you mean?*
SILSM1086	:	*From the inequality model that has been made, then finding the point of intersection that the x-axis and y-axis traverse in each inequality is correct. From the results of the image, it is correct, it is found that the intersection point of 2 inequality lines is found, so by elimination, the intersection point is found which is the maximum point and gets the maximum profit.*
PSM1087	:	*Oh, I see. Is there any other way?*
SILSM1087	:	*No other way.*

Figure 4. Excerpts from the researcher's interview with subject 1 (SILSM1) at the phase of re-checking the solution.

After SIL saw the question and matched it with the answer that had been written, SIL declared it was correct and correct [SILSM1082] [SILSM1084]. This stage is the determining stage, whether the solution obtained by SIL is the answer to the problem. SIL is given the opportunity to re-examine the solution that has been obtained as a whole. Beginning with SIL by looking at the questions with answers that have been written, then paying attention to the tables that already contain algebraic expressions. In conclusion, SIL states that the mathematical inequality model created is in accordance with algebraic expressions. In this case, SIL shows an indicator of algebraic thinking (P4A1). SIL looks for the intersection of the x-axis and y-axis, from the results of the image it gets the intersection point on 2 inequality lines so that by eliminating it finds the maximum point to get the maximum profit [SILSM1085] [SILSM1086]. SIL rechecks each step, until it finds the maximum point of intersection of the x and y axes on each inequality, paying attention to the image of the solution area that has been shaded and 3 points that have been bolded until it succeeds in getting the maximum benefit from the calculation of the equation of the objective function (P4A3). So SIL interprets the maximum point obtained in the form (x, y) as the value of the variable in question. The variables x and y are referred to as the first and second series, respectively. So that SIL gets the maximum benefit and is a solution to these problems. SIL also states that there is no other form or expression to solve this problem. This shows the SIL indicator of algebraic thinking (P4A4).

Based on the results of the SIL interview on the completion of linear programming tasks, it can be described the SIL algebraic thinking profile scheme in solving problems (linear program tasks) based on Polya's problem solving steps, as presented in Figure 5. At the stage of understanding the problem, SIL finds important elements and components based on known problems, SIL can also identify the questions asked, and compile simple mathematical algebraic equations (algebraic expressions) based on problems. SIL defines the meaning and suitability between coefficients, variables, and constants (forms of algebraic expressions) based on an agreed definition. At the stage of making a solution plan, SIL reveals a plan for the steps to solving the problem, starting from the idea of making a mathematical model (equations and inequalities) based on algebraic expressions. Based on this idea, SIL describes the solution area on the graph (coordinate of the axis), so that SIL has been able to predict that a value will be obtained as a solution. SIL has also been able to calculate the maximum profit using the objective function equation. These results are in line with the findings (Ashar et al., 2021) that students with high thinking skills are able to write and describe mathematical models, apply the properties of absolute value inequalities, and are able to get the right answer. Generally, if students are faced with math problems (questions) by 38% of students fail to understand the problem and 14% of students fail to develop a settlement plan (Nuryah et al., 2020). However, in the case of SIL which is faced with linear program problems, SIL is able to understand the problem and develop a problem-solving plan, as shown in Figure 5.

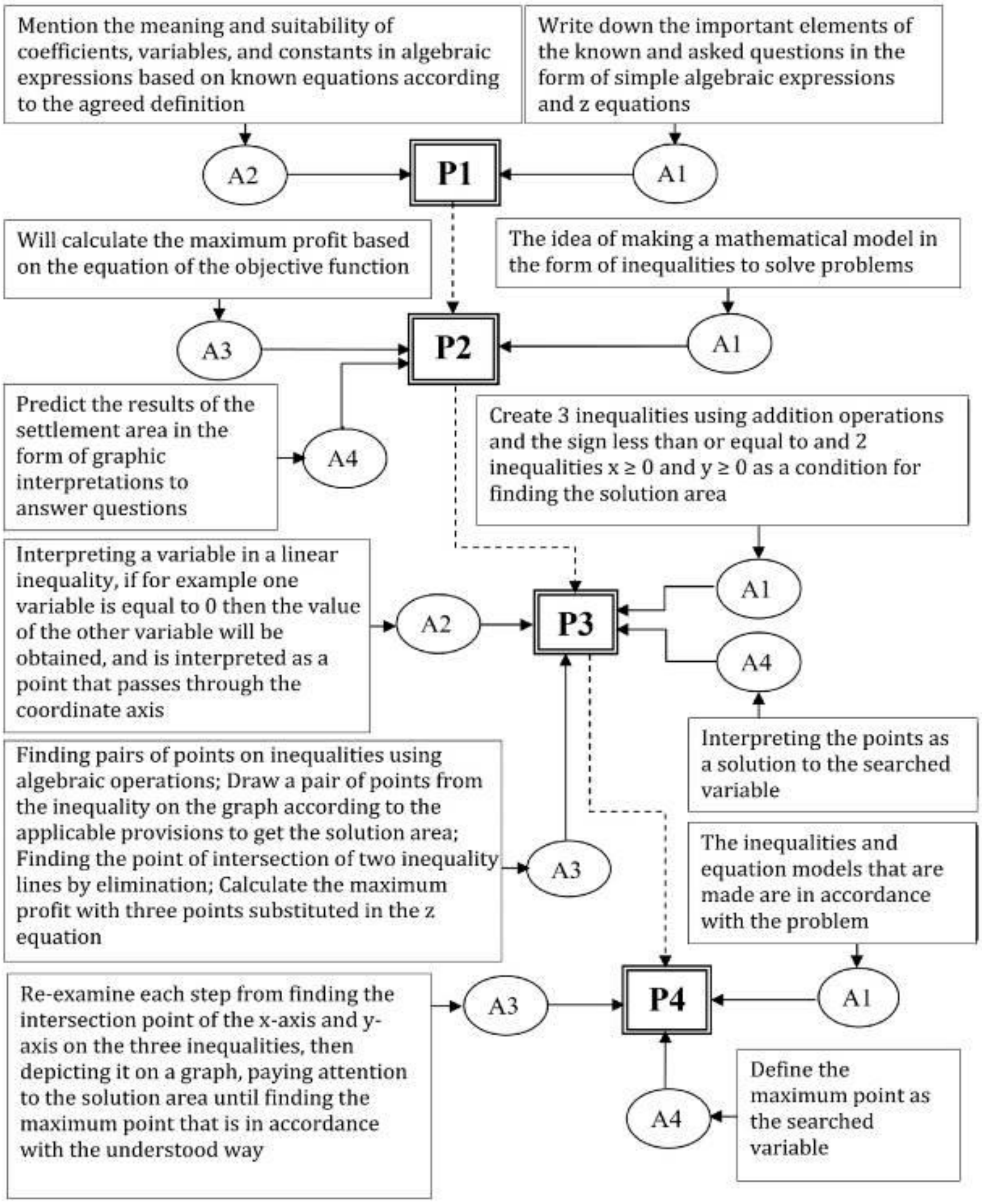

Figure 5. Schematic profile of SIL algebraic thinking in solving mathematical problems based on Polya's problem solving steps

At the stage of implementing the completion plan which is the implementation stage of what has been planned by SIL. SIL makes a mathematical model in the form of inequalities that are appropriate to answer questions of three inequalities. In this inequality, SIL interprets a variable in an inequality if one of them is made equal to 0 then the value of the other variable will be obtained by converting it into an equation first. In addition, by assuming equal to 0, according to SIL it has to do with describing points on the x-axis and y-axis. Of the three inequalities, SIL uses the operations of multiplication, addition, subtraction, and division to obtain the value of x and value of y according to the applicable algebraic law in order to obtain a pair of points that can help answer the next question. From the pair of points obtained from the three inequalities, SIL describes the pair of points on the graph according to the applicable law so that the solution area is obtained. Based on the settlement area, SIL sees that there is a point that is suspected to be the maximum point. Then SIL looks for the point that intersects on 2 lines by elimination according to the applicable algebraic law. SIL uses multiplication, addition, subtraction, and division operations by substituting the value of x and value of y in an objective function equation based on applicable algebraic laws so that maximum profit is obtained which can help answer the next question. SIL explains the final solution obtained as a solution to the problem according to the context of the problem. Solving problems with the right number operating system is accuracy in the use of algebraic thinking (Tsaqifah, 2020).

Finally, the stage of re-checking the completion. At this stage SIL states that the inequality model that has been made is in accordance with the algebraic expressions in the table. Likewise, the equation of the objective function that has been written based on the story in the problem. SIL re-examines each step until it finds the maximum point from looking for the intersection of the x-axis and y-axis on each inequality, paying attention to the image of the solution area that has been shaded and 3 points that have been bolded until it succeeds in getting the maximum benefit from the calculation of the equation of the objective function. So SIL gets the maximum benefit and is the solution to the problem. SIL also stated that there is no other way to solve this problem. Until this phase, it seems almost the same as the findings of previous studies that students interpret the solution as a variable obtained from the intersection point in the solution area to get the maximum benefit (Hardiani et al., 2018).

D. CONCLUSION AND SUGGESTIONS

The results of the study have described the profile of students' algebraic thinking with Polya's problem solving strategy in completing a linear program carried out on male students with field independent cognitive style. Through Polya's problem solving, the profile of students' algebraic thinking has been described, where SIL has represented mathematical ideas using algebraic expressions in the form of equations, inequalities, or functions; SIL defines coefficients, variables, and constants in algebraic expressions; SIL uses equivalent symbolic representations to manipulate formulas, equation expressions, inequalities or functions using algebraic conventions; and SIL can interpret the solution. Based on the results of this study, we suggest further studies to be able to develop a prototype learning model that can train algebraic thinking intensively, of course this is based on the thinking profile that has been described.

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