

## Refractive Thinking with Dual Strategy in Solving Mathematics Problem

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**Abstract:** The purpose of this article was to explore and classifies the processes of students refractive thinking with dual strategy in solving mathematics problems. This study used a qualitative approach involving 25 subjects and this article the authors describe one subject the refractive thinking with dual strategy. The results of dual strategy refractive thinking show subject need two alternatives In the process of decision making. If there are sequence of district the same, subject uses internal comparison as consideration, for example considering the mode of sequence before and after.

**Keywords:** refractive thinking, critical thinking, reflective thinking, mathematics problem

### I. Introduction

Downey (2005) using a metaphor light to describe the refraction. Refraction is process light hit a medium thus result reaction which triggered the refraction of light towards a certain point. Based on the metaphor, Pagano & Roselle (2006, 2009) and Medeni & Medeni (2009) states that the refraction occurs because of the reflection continued critical thinking and produce new knowledge. Therefore thinking is signed with reflective thinking continued critical thinking till produce decision called refractive thinking. This indicates that an important component of refractive thinking is reflective thinking, critical thinking and decision (product). The process of refractive thinking can be illustrated in Figure 1.

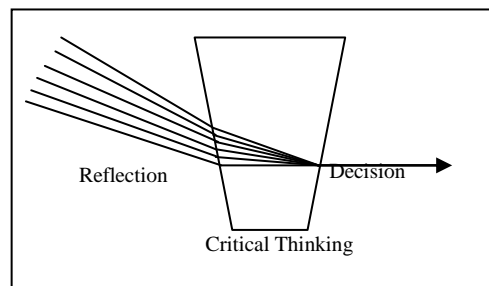


Figure 1. The Process of Refractive Thinking

Pagano & Roselle (2006, 2009) defines the refraction is the transformative knowledge that occurs the which validates the use of critical analysis and problem solving providing interpretation and Conclusions of important issues and situations considering the course content and context. Knowledge transformative in this case is ability of person resolve problems through some alternative solution. Pagano & Roselle (2006, 2009) that purpose of refraction is process decision-making by considering some possible alternative solution. This shows that the refraction is focusing of information since there are some alternative solution obtained when reflection and do critically analysis as consideration to establish a decision. Be related with refraction, Medeni & Medeni (2009) defines refraction is new knowledge acquisition from critical thinking of reflection. This shows that the refraction is the process of acquiring new knowledge (decision) resulting from reflection and critical thinking. Therefore refractive thinking this study is process of decision making through reflective thinking continued with critical thinking.

Reflective Thinking is a thinking process that is important in construct of knowledge. Schon (1991) defines reflective thinking is signed with perception of someone about something which disturbing or trouble, then someone doing experiment so that provide an understanding of the problem to be solved. Relating to reflective thinking, Dewey (1933); Sezer (2008); Rosen (2010) and Gurol (2011) suggested that reflective thinking is a process occurs when someone experiencing perplexity and then conducting an inquiry repeatedly until find the solution. Based on some notion reflective thinking, implicitly important component of reflective thinking namely perplexity and investigation.

Reflective thinking is initiated by the perception of something troubling or promising, and it is determined by the production of changes one finds on the whole satisfactory or by the discovery of new features

which give the situation new meaning and change the nature of questions to be explored (Schon, 1991). This shows that, reflective thinking signed with difficulty (trouble) experienced by person so that he doing continuously behavior changes. Behavior changes are the process of investigated with explore information on the problem. Investigations done to resolve the situation of uncertainty, instability, uniqueness, and conflict so that as provide answers the questions. Based on the above definition reflective thinking, implicitly there are some components of reflective thinking. Two opinions can be compared. Implicitly, Based on the similarities in the nature of each component, the obtained result of the development of reflective thinking in this article, namely: (1) Trouble partial indicator illustrated also in perplexity, such as someone difficulty in problem solving. Perplexity developed by Dewey is not just in trouble, but rather confirms the existence of doubt or lack of confidence their completion. If students are having trouble, doubt or confusion in solving the problem then it is said the students experienced perplexity; (2) Inquiry can be compared with the experiment, because the inquiry has the same properties as the problem that is causing the effort provide a solution. In the process of looking at the problem, a person can remember what you learned and utilized to solve the problem. The process is known as behavioral changes. In other words, students conduct an investigation by leveraging existing knowledge to look back the settlement process due to a lack of confidence or doubt in obtaining answers. Students who experience the process said investigation. Therefore reflective thinking in this article is the thinking process that signed the perplexity and then conducted an investigation till find a solution to the problem (Prayitno, 2014).

Related with critical thinking, Pagano & Roselle (2009) states that critical thinking is signed with process of evaluated various relevant information which obtained when the reflection in solving problems. The implicitly "evaluation" are revealed by Pagano & Roselle (2009) is process of selecting some of alternative settlement which obtained when reflection so that it can be taken into consideration to make a decision. Fisher (2001) states that critical thinking is signed the activity of skilled interpretation and evaluation of the information and statements. Interpretation usually construct some settlement and produce alternative. Additionally, the evaluation is process of determining something. Evaluation is signed by selecting the best of some of alternatives (Plymouth University, 2010). Based above definition critical thinking, implicitly there are some components of critical thinking. Components of critical thinking according to Fisher (2001) is interpretation and evaluation. According to Pagano & Roselle (2009) is Opinions gathered and evaluation. Implicitly, Based on the similarities in the nature of each component, the obtained result of the development of critical thinking in this article, namely: (1) Gathered opinions can be compared with the interpretation, because it has the same properties that produce alternative possibilities completion. The possibility of constructing an alternative solution requires a variety of information that has been collected in the process of reflection. The situation is known as construction (construct); (2) Evaluation of critical thinking Pagano & Roselle (2009) and Fisher (2001) can be compared as in selecting or evaluating an alternative solution or answer. This component signed by evaluated alternative solution or answer based considerations. This component is known evaluation. Therefore critical thinking in this article is thinking process that signed the construct and evaluation alternative settlement and the best answer based on various considerations (Prayitno, 2014).

Some researchers have review the reflective thinking as process towards critical thinking, among others: reflective thinking is the one tool to develop higher-level thinking (Park & Kastanis, 2009); critical thinking is the result of one's reflection in learning (Asare, 2012); reflective thinking to support critical thinking skills in solving social and political problems (Dawe, et al, 2005); reflective thinking increases one's critical thinking and understanding which learned (Park, 2011); reflective thinking the beginning of the process of critical thinking specifically refers to the process of analyzing and making judgments (Colley & Billics, 2012; Choy, 2012); Reflective thinking is the key of critical thinking (Colley & Billics, 2012). In the study, Doerr & English (2003) showed the students experienced when using phase shift in thinking reflective thinking and critical thinking so as to produce variations of the model answers. However Doerr & English (2003) did not review how the thinking of students in produce the answer. Whereas Pagano & Roselle (2009) write a study of refraction theoretically and not review in the mathematics education. In the research have not provided description about how process of reflective thinking continued to critical thinking till produce decisions. Therefore this article review the process of reflective thinking towards critical thinking till produce decisions called as refractive thinking.

## **II. Method Research**

In this study, students were asked to complete task and expresses out loud what he was thinking (Think Out loud) when solving problem. After students obtain settlement, research check the students process settlement correct to obtain answers. If student experience reflective thinking and critical thinking in produced decision, then student will be a subject and included in the group refractive thinking. Each group is filled by two research subjects. If not obtain the desired subject, then the given the task again to students. The process of selecting subjects performed until a saturation of the data, its meaning that appears the same or remain

characteristics of some subjects for each category. The many research subjects for each reflective thinking is 2 subject. Determined 2 subjects, with consideration that the method analysis used the constant comparative method. The purpose of this study was to explored and classified the processes of students refractive thinking in solving mathematics problems. Refractive thinking indicated from the process of students construction against instrument task "decision-making". This study used a qualitative approach, since according to characteristics owned. The research was carried on students in semester second. For this purpose, the research took the data on student at Universitas Wisnuwardhana Malang and Universitas Negeri Malang. Research subjects not randomly selected, However taken with considered his communication skills so disclosure of the thinking process can be done well.

The task sheet instrument "decision making" used in this research is the development of a decision-making instrument from Doerr & English (2003). The development problem of this research, among others: First, the characteristics of the data. Data presented by Doerr & English (2003) is an ordinal data, meaning that the data presented contain differences in sequence (tiered). The data this article is a data interval, meaning that data presented only give information about each object (district). Second, the decision-making process. Decision making problems presented by Doerr & English (2003) directly. It means that the subject can make decisions only by summing and dividing numbers then sorted. Problems in this article is problem decision making of indirect. That is, problem can be solved by add the numbers of each object then grouped, ranking, sum or divided then sorted. Three, consideration in making a decision. Decision making problems presented by Doerr & English (2003) was influenced by quantity that is the magnitude of numbers each object. Problems in this article are influenced by quantity and quality that is large and increase of numbers each object. The problem given to the students as follows.

Local Revenue Offices survey 6 district to find out the level of district dependence on the central government. The dependence of regional on the central government can be measured based contribution the Own-Source Revenue (OSR) to income of province. If the contribution of OSR greater and increased then the district dependence to central government is getting low. The value in table below shows the percentage contribution of OSR to income of province based Natural Resources (NR) for three years.

District	A			B			C			D			E			F		
	Tk.1	Tk.2	Tk.3	Tk.1	Tk.2	Tk.3	Tk.1	Tk.2	Tk.3	Tk.1	Tk.2	Tk.3	Tk.1	Tk.2	Tk.3	Tk.1	Tk.2	Tk.3
NR livestock	19	9	19	12	24	15	14	22	17	23	14	23	21	15	14	11	16	12
Maritime	18	20	13	9	19	19	12	23	17	24	8	8	19	12	19	18	18	24
Forestry	20	15	19	13	18	18	17	19	15	23	13	11	18	18	10	9	17	27
Plantation	9	11	26	23	17	14	20	22	15	17	16	14	16	24	15	15	10	16
Agriculture	25	14	20	14	13	15	19	15	24	16	24	14	16	18	9	10	16	18
Fishery	12	23	8	19	14	24	7	13	9	15	16	21	24	9	23	23	25	15

The brother task is determine the order of district from the lowest to the highest dependence on the central government! Give an explanation for your answer!

**Figure 2.** Instruments Task

### III. Results And Discussion

This study used a qualitative approach with the involvement 25 subject. Of the 25 subject, 10 subject grouped into refractive thinking with single strategy; 9 subject are grouped into refractive thinking with dual strategy, and 6 subject are grouped into refractive thinking with multi strategy. In This article the authors describe the dual strategy of refractive thinking with 1 from 9 subject. The results of the process of refractive thinking are presented in Table 1.

**Table 1.** The results of the refractive thinking presented by students when solving decision making problem.

Refractive Thinking		
Single strategy	Dual Strategy	Multy Strategy
10	9	6
40%	36%	24%

#### *Characteristics of Refractive Thinking with Dual Strategy by Subject 2 (S2)*

In the process of thinking, appears that S2 have difficulties to solve problem. It appears that S2 repeatedly read problem to understand. This indicates that the S2 experienced perplexity.

S2: (repeated read of problem) *District A, B, C, D, E, F and Own-Source Revenue, what to do...*

The statement above shows that S2 experienced confusion. Efforts made by S2 to overcome them by reading problem repeatedly till they know the problem to be solved. Known problem with the statement is indicated by S2 "hmm.. means the dependence of district to central measured ... there is the contribution of OSR and increase OSR...". S2 directly show that problem is determine the dependence of the district. The next process, S2 utilize the existing knowledge to represent contributions OSR with summed of contributions for

three years. To explore the thinking process by S2 when solved with summed of contribution every three years, then researchers conducted interviews. The following interview between researchers and S2.

R: why do you used such settlement this?

S2: since the question is to determine sequence dependence of district, and there sentence if the great of contributions and increased then low dependence. So that I showed first the great contribution of district each Natural Resources. based on the amount, I can determine the sequence of district. So here must be added all of them

In quote of the interview, S2 solved with summed the percentage contribution of each district based Natural Resources (NR). The process called analytical process, which is a process that describes the problem into several parts so that the parts are then completed. The summing is done by S2 begins by calculating the percentage contribution of livestock. S2 summing the percentage contribution of the farm for three years in each area. This process is carried out from the district A to district F. The following by summed the contributions for three years by S2.

SDA/Daerah kota A.	kota B	kota C	kota D	kota E	kota F
Peternakan	47	51	53	60	39
kelautan	51	47	52	40	60
kehutanan	54	49	51	47	53
Perkebunan	46	54	57	47	41
Pertanian	59	42	58	54	44
Perikanan	43	57	29	52	63

Based on the above answers, S2 summed the livestock contribution percentage of each district. Livestock on the district A is 47, the amount obtained with summed the percentage of contributions every three years (19 + 9 + 19). District B is 51 obtained by summed the contributions for three years (12 + 24 + 15). The process continues until the district F. Based on the amount result, S2 grouped and sorted the district have a large till small of contribution amount. District have largest amount, collected in the first order. While the district has small amount, grouped in the last order. Process conducted by S2 is interpretation the problem of "district sequence".

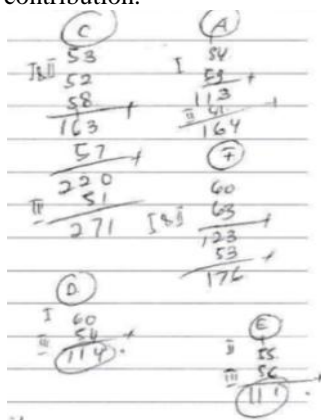
The District order first on the livestock is district D, C, B, E, A and F. This is because the amount of district contribution to livestock the greatest is district D i.e. 60, then district C is 53 and smallest amount is district F i.e. 39. While in maritime, district F is a district order first because it has the highest amount of contributions compared to other district i.e. 60. Then continue district C with contribution amount 52 and district last order is district D with contribution 40. The group process and sorted performed by S2 until fishery. The following settlement obtained by S2.

Peternakan	D, C, B, E, A, F
Kelautan	F, C, A, E, B, D
kehutanan	A, F, C, B, D, E
Perkebunan	C, E, B, <del>F</del> , D, A, F
Pertanian	A, C, D, F, E, B
Perikanan	F, B, E, D, A, C

The next process, S2 combines the sequence a whole. In the process of combining sequences, S2 connects sequence with rank . It can be seen from the statement S2 "... makes the rank first, A, B, C, D, E, F, and rank 1, 2, 3, 4, 5, 6". This indicates that S2 experience process of critical thinking (Pagano & Roselle, 2009 and Fisher, 2001). The statement indicates that the S2 explicitly show relationship of district with ranking. S2 connected ranking with district have greatest to smallest of contribution amount at each Natural Resources. S2 grouped based many district have rank with Talley. The following settlement with Talley by S2.

	1	2	3	4	5	6
√ A	(II)		I		II	<del>III</del>
B		I	(II)	I	I	I
√ C	I	III	I			I
√ D	I		I	II	<del>III</del>	I
E		I	(I)	II	I	I
√ F	(III)	(I)		<del>III</del>	I	II
	6	6	6	6	6	6

The work result above indicates that ranking one is A, C, D, F. District A and F as much as two, meaning that the district A appears twice in the first order in forestry and agriculture. Similarly, F appear twice on maritime and fishery. District C and D as one, meaning that district C and D appear only once in the first order in each Natural Resources i.e. plantation and livestock. Based on grouped, S2 thinking for a long while show the first order district A and F. "This is the same the same, ranking one twice ..." S2 experience difficulties when conclusion answer. After thinking for a long time, S2 continued settlement with connecting of sequences and amount of contributions in each district. S2 calculate amount of contributions the first and second of sequence. In the first order, district C occupy in plantation with total contributions 57, while the second order occupies the livestock, maritime and agriculture with the amount of 53; 52; and 58. S2 adding overall i.e.  $53 + 52 + 58 = 163$ , then summed with 57 thus obtained 220. The likewise in district F, A, and D. The following answers by S2 related to amount of their contribution.



In determining the sequence of district, S2 show solution alternative by adding the contribution of Natural Resources. Based on process doing by S2, obtained the amount contribution of overall namely district C be 271, district A be 164, district F be 176, district B be 162, district D be 114 and district E be 111. Based on settlement process done, S2 make decisions about order lowest to highest of dependence namely, district C, F, A, B, D, and E. The following answers district sequence from lowest to highest dependence obtained S2.

*Az PAD dari yg terbesar ke yg terkecil.  
C, F, A, B, D, E*

S2 believe the answer, as reinforcement on answers obtained, he uses another strategy. This is indicated the behavior by S2 "Here A ranking one times two and also F, why I put in rank two and three?". This shows that S2 experience perplexity when answer. S2 recalculate in each district. based on the settlement, S2 made mistake on previous calculation is the total number in the F. This behavior indicated by statement S2 "(counting of district F), .. why the difference in 10, Hmm..41". S2 make improvements on the amount of contributions the district F which affects the district grouped based on their Natural Resources "means plantation of C, E, B, D, A, F, F is ranked sixth, so F ranked last in the estates" that have impact on grouping as whole. This indicates that the S2 experience reflective thinking (Dewey, 1993 and Schon, 1991).

	1	2	3	4	5	6
√ A	(11)		1	1	1	1
B		1	(11)	1	1	1
√ C	1	1	1			1
√ D	1		1	1	1	1
E		1	(1)	1	1	1
√ F	(11)	(1)		1	1	1
	6	6	6	6	6	6

Based on above settlement, S2 attention district that are above (first order). The first sequence of the district there are four choices of district A, C, D, and F. S2 connected one district to other district of sequence, in this case S2 compared district A, C, D, and F. Based on this comparing, many district (mode) the first sequence is same. District mode C and D is one, while district A and F is two. S2 selecting A and F as first sequence district, based on the first sequence mode. The following statement by S2 with regard to selecting A and F.

S2: *When seen from this table, the first rank of greatest possibility are A and F .... District F superior to A because F is ranked one twice and two one-time rankings. while A in third sequence*

The statement above shows the first sequence is A and F because the district is first sequence twice, while other district only one time. Then, S2 compared A and F with sequence thereafter (second). In sequence afterward (second), mode of district F is one, while areas A no mode. S2 identify the sequence thereafter (the second) for consideration determining the first sequence. S2 choose F as district in first sequence, while A is chosen as district in the second. This is because the district A ranks first as much two and rank second as much three. The following answer by S2 with regard the first and second of sequence.

- ① F menempati ranking pertama terbesar karena f berada pd ranking 1 → 2x & ranking 2 → 1x  
 ② A menempati ranking 2 terbesar karena A berada pd ranking 1 → 2x

The next process is third order. To determine the sequence of third, S2 compare district B, C, D and E. Based on four district, S2 comparing many district in the first sequence. In the first sequence that appears only district C and D as many one. Furthermore, S2 consider the order after namely the order of two and three. The processes performed by S2 analogous with the first and second order. District C is rank one as much one and rank two as much three. While the district D, ranking one as much one and ranking three as much one. Based on district ranks first, second and third, then S2 choose the district C as district that ranks third and D as district which ranks fourth. This is because the district C excelled in second, while the region D in third place. The following work by S2 related to the third and fourth.

- ③ C menempati ranking 3 terbesar karena c berada pd ranking 1 → 1x & ranking 2 → 3x  
 ④ D menempati ranking 4 karena D berada pd ranking 1 → 1x & ranking 3 → 1x

The next process is fifth. S2 looked back at remaining district, namely B and E. S2 connects the district B and E based on the second and third sequence. In the second sequence, district B as much one, while E as much one. Shows that the district have same mode in second order. S2 choose alternative of compared that is third sequence. District B in third order as much 2 while district E only 1. Based on third order, district B is more dominant than district E. This third sequence is consideration by S2 to determine the fifth and sixth sequences. The following result work by S2 the fifth and sixth.

- ⑥ E menempati ranking 6 karena E berada pd ranking 2 → 1x & ~~3~~ ranking 3 → 1x  
 ⑤ B menempati ranking 5 karena B berada pd ranking 2 → 1x & ranking 3 → 2x

Based on settlement process, S2 make decisions about sequence from lowest to highest dependence on district F, A, C, D, B, and E. Conclusions are based on compared many district (mode) in certain sequence. The following answers district sequence from lowest to highest dependence obtained S2.

Jadi yang memiliki ketergantungan dari yg terendah ke yg tertinggi adalah F, A, C, D, B, E

With these answers, S2 believes the answer. In the process of decision making, subject not only need a single strategy, but he made another settlement as reinforcement for answers obtained. Based on the thinking, S2 experience refractive thinking with dual strategy. The process of refractive thinking with dual strategy by S2 can be illustrated in Figure 3 below.

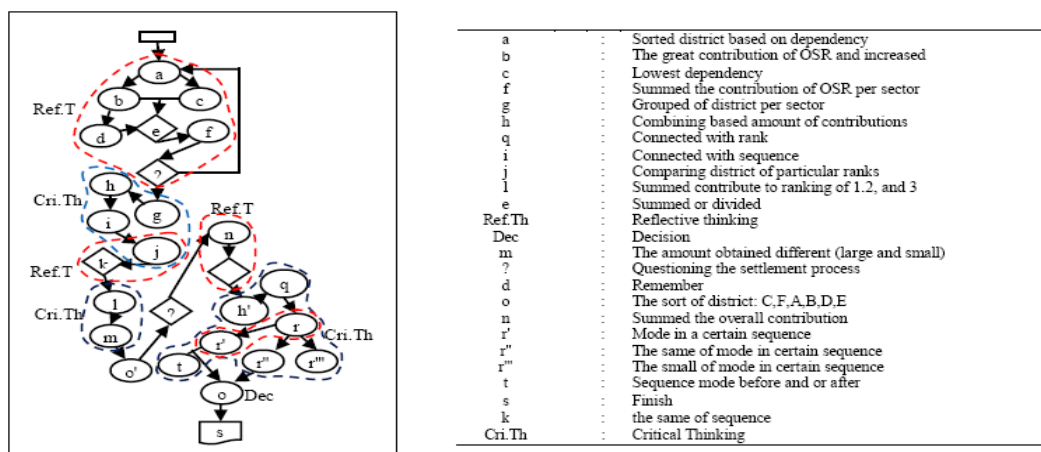


Figure 3. The Process of Refractive Thinking With Dual Strategy by S2

If review from framework by Dewey (1993) and Schon (1991) states that reflective thinking is process occur when someone experience perplexity or trouble thereafter doing investigation to overcome uncertainty, instability and conflicts by students. The produce of decision, the subject only consider some information as comparison, for example considering the mode of sequence before and after. in this case, someone experience critical thinking. If review from framework by Pagano & Roselle (2009) and Fisher (2001) states that critical thinking is process that signed the construct and evaluation alternative settlement and the best answer based on various considerations.

Based on the description above, it can be described that the scheme of dual refractive by students in solving mathematics problem has been based on Refraction theory (Pagano & Roselle, 2009). The process of refractive thinking with dual strategy begins when student finds of perplexity. Then, they conducted investigation to problem till obtain information "sequence". Based on that information, they grouped and sorted of district based Natural Resources. The process of grouped based on strategies add up contribution per Natural Resources. In this case they experience reflective thinking. To make decisions, they consider mode only in the first sequence. In this case they experience critical thinking. The next process, they use other strategies, namely

ranking to believe the decisions by them. It is based on the information "determine of sequence" means "rank". If obtained district the same in particular sequence, students compare the mode of district in the rank before or afterwards. In this case they are re-experience critical thinking. This process continues until resulted the decision (Figure 4)

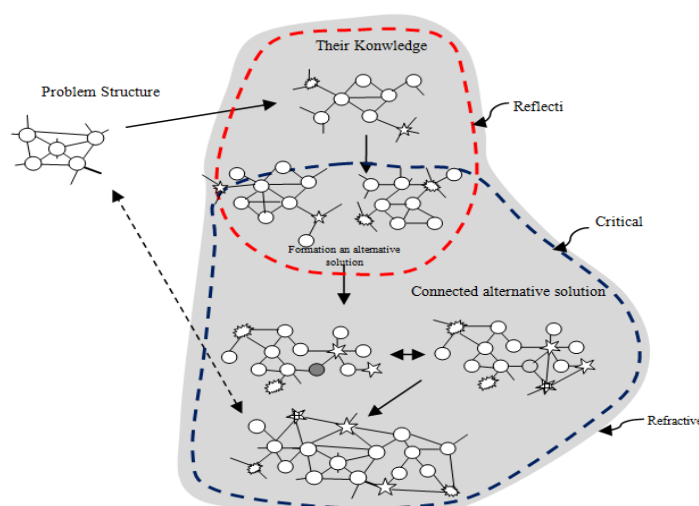


Figure 4. The Process Refractive thinking with Dual Strategy Based Theory Pagano & Roselle (2009)

#### IV. Conclusion

The process of refractive thinking with dual strategy begins when student finds of perplexity. Then, they conducted investigation to problem till obtain information "sequence". Based on that information, they grouped and sorted of district based Natural Resources. The process of grouped based on strategies add up contribution per Natural Resources. In this case they experience reflective thinking. To make decisions, they consider mode only in the first sequence. In this case they experience critical thinking. The next process, they

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