

Longitudinal Study Process Cognitive for Mathematics Education Students In Problem Solving Mathematics and Physics

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Abstract. The objective of this research is to obtain a description of the process cognitive development of mathematics education student by *longitudinally* in *problemsolving* mathematics and physics. The research subject is mathematic education students FKIP Tadulako University-Indonesia, which consists of one person capable of high mathematics and one person capable of low math ability. The development of the process cognitive explored by giving two math problems, such as equation of a straight line (M1) and integral (M2) and two issues of physics, the problem of the equation of a straight line of motion (F1) and the distance equation of a straight line (F2). This problem is successively given in the even semester of 2016/2017 and 2017/2018 odd semester on the same subject that is the subject of high mathematical ability (ST) and low (SR) based on Polya step. The results showed that the process cognitive both *a problem solver* in the even semester when math problems are more likely to understand through pictures. Based on this insight ST and SR plan M1 solution by connecting the knowledge they already had (formula equation of a straight line) with the problem given. However SR cannot use the formula well and cannot give a detailed description of the solution. Solving M2 by ST, when planning only think of all available information on the issue, consequently the results are not the same as solving the M1. In contrast with SR that can connect prior knowledge, so can successful in solving M2. Problem solving for F1 and F2, cognitive process ST and SR is the same when both are facing the problem of M1 and M2. The cognitive process ST and SR in the following semester (odd semester) observed that when understanding the problem is the same with the previous semester. Unlike when making plans, ST strategize with detailed and comprehensive information both on the M1 and M2. On completion of the F1 and F2, ST utilize mathematical knowledge they already had, so they can finish it in a systematic way, while SR can not do as was done by ST.

Keywords: Cognitive thinking, longitudinal and problem solving.

INTRODUCTION

Thinking process is one important thing to note for a person who is having a problem, because by knowing the person's thinking process, it can easily be given a way out of the problems encountered.

The process of thinking is a mental process that is internal which can not be observed directly, but can be researched through using certain methods of interpretation abilities when solving problems. Solso (1995) says that a person's mental activity can be determined by giving the problem to be solved, then observe the thought processes that arise in solving the problem. The thought process that can be observed in solving problems such as what is written or what is spoken. Metallidou (2009) states that solving the problem is the thought process that is directed at that goal requires the proper mental representation of the problem and the application of a particular method or strategy for achieving the desired objectives.

Pribul and Bodner (Solaz-Portoles and Lopez, 2007a) stated that early stage in the process of problem solving includes the release (disembedding) relevant information from the statement of the problem and rearrangement or

transformation of matter into understandings of individuals and an important part in determining the success of the process problem solving. Atkinson (1979) states that the information received through the senses is processed in various ways and combined with the existing information, changed and rearranged. Storing information means to maintain the information that has been received in memory. The recall information from memory is defined as the recall information. In the process of recall, a person can recall information without the presence of a specific object. This means that the recall can be caused from inside a person, not because of the influence of a particular object. Therefore, the process of thinking in problem solving allows a person to be reviewed from time to time.

Luis Terman (in Sunardi&Sujadi, 2017) has been conducting research followed the development a group of genius from preschool to adulthood when they have reached an established career and life. The different characteristics at any time that is assumed to be a stage of development.

The development of thinking process is also determined by the experiences that have been obtained, if the same information encountered with previous experience then a person is not experiencing development. But when new information is received contains new aspects, then in others it happens a process of adaptation schemes that have been established by the stimulus (structural problem) recently received, so that a person is experiencing development. Piaget (Hergenhahn& Olson, 2009) states that the process of adaptation schemes that have been formed with new stimulus can be done in two ways that is assimilation and accommodation. Assimilation is a process of integrating the new stimulus directly into the existing scheme. Suparno (1997) says that assimilation is the process of integrating perception, concept, or a new experience into the scheme or pattern that already exists in the mind. Piaget (Brooks & Brooks, 1993) states assimilation is the incorporation of new events into intelligence as a scheme or concept. In assimilation, the stimulus is interpreted based on the scheme which is owned by a person. If the incoming stimulus structure in accordance with the existing scheme, then a person can directly respond to the stimulus. In assimilation a person no longer need to change the existing scheme, because of the structure of matter accordance with a scheme that has been provided. Wadsworth (1989) says that assimilation does not cause a change / replacement scheme, but the scheme development. Based on the description above it can be concluded that assimilation is the process of integrating the new stimulus without changing the scheme because it has been matched with the stimulus received.

Accommodation is the process of integrating the new stimulus through the conversion of the old scheme or the formation of a new scheme to adapt with the stimulus received. Piaget (Brooks & Brooks, 1993) explains that "accommodation, existing schemes are modified to account for new information". Stimulus received may not correspond to the old scheme, therefore the old scheme should be adapted or modified to suit the incoming stimulus. A schema is a mental or cognitive structure that the mental structures that people intellectually adapt to the surrounding environment (Skemp, 1982). The scheme used to process and identify the stimuli from the outside. Bartlett (Devis& Tall, 1999) states that the scheme serves as a guide in organizing information (knowledge) are included in the memory system on a body of knowledge. So this scheme to identify the functions to process incoming stimuli and can lead in organizing the incoming stimulus.

The process of assimilation and accommodation is due to disequilibrium that is a process of structural instability think because of the stimulus / issue received that can not be solved immediately. Schunk (GoK, 2010) states that the problem occurs only when a person is faced with the difficulty that the answer is not immediately available. Anderson & Krathwohl (2001) stated that the problem is the task of the settlement procedure is not yet known, so it should look for the procedure to complete. Both of these processes will take place continuously, until reach the equilibrium condition result; It is a condition of stability in the structure of thinking. This is achieved when found a way out of the problems encountered. According to Weisberg (2006) that if you find a way to change the state of matter into the desired goal, then you have solved the problem. BouJaoude&Barakat (2000) states that solving the problem means finding the right way to solve the problem.

Assimilation makes it possible to respond to the situation according to prior knowledge. However, not all situations can be responded based on previous knowledge (because there is a new aspect), then the new aspects of this experience leads to cognitive instability. This condition happen continuously, so the mental state changed in order to incorporate new aspects into the experience and cause the structure to think in equilibrium condition. In this assimilation process, the information entered in the form of the structure of matter captured by the senses (sense of sight), and along with it the brain begins to process it by associating or adapt with the existing scheme. If the incoming trouble structure is in conformity with the existing scheme, then immediately integrate the structure of matter based on the scheme owned. On the condition that occurs is the process of assimilation. If the structure of the problem that had entered in accordance with the existing scheme, then there needs to be changing the old scheme or the formation of a new structure so that the structure of thinking in accordance with the structure of the problems encountered, on the condition that occurs is the accommodation process. Based on this description suggests that the process of accommodation is necessary, because with this process indicates that the person's thinking process has reach the development knowledge.

Suparno (1977) says that the process of assimilation and accommodation necessary for cognitive development of an individual. Piaget (Hergenhahn and Olson, 2009) says that if the assimilation is the only cognitive processes, then there would be no intellectual development because people will just assimilate his experience into cognitive structure. Therefore accommodation as a process to modify the cognitive structure is essential to generate mechanisms of intellectual development.

Every new experience will lead to assimilation or accommodation. Someone responds to the world based on previous experience (assimilation), but every experience contains different aspects with previous experience, different or unique aspects of this experience that causes cognitive changes (accommodation).

This description suggests that someone who has experience in solving problems, the ability to solve problems will also be better, despite the problems encountered is different with previous experience.

Based on this, the study examines trying to see the longitudinal thought process math students in solving and mathematical problems using mathematical physics. By knowing the development of student thought processes on an ongoing basis, it can easily provide a way out of the problems encountered in the study.

METHOD

The method used in this study is longitudinal method, researchers observing and studying the development of the thinking process of problem solving in mathematics and physics education student UNTAD with high math ability (ST) and low (SR) for two consecutive semesters the even semester of 2016/2017 and odd semester 2017/2018. The process of thinking problem solver traced by steps of Polya (1973), when understanding the problem, making problem solving plan, implement the plan and when to re-examine the work that has been done. These data were taken by observation, thinking-aloud and interview and a written test as well as analyzed using the technique proposed by Miles and Huberman (1994), namely data reduction, data presentation, and conclusion. However, before analysed, performed using a triangulation method credibility test, that is the interview and thinking-aloud.

The instrument used, besides researchers themselves as the main instrument also use supporting instruments such tests math skills as well as mathematics and physics problems outlined in Tables 1 and 2.

Table 1. Problems of Mathematics and Physics the even semester of 2016/2017

Group	The even Semester 2016/2017
P. Mat	<p>a. Determine the equation of a line from the following chart.</p> <p>b. What is the meaning of the graph. Perform interpretation!</p> <p>c. Get the equation $g = y_0x + \frac{1}{2}mx^2$ from the equation of the line that you earn in part a.</p>
P. Fis	<p>a. Find the equation of motion of an object that is represented by the following graph.</p> <p>b. What is the meaning of the equations of motion of the graph (did interpretation).</p> <p>c. Get equation $s = v_0t + \frac{1}{2}at^2$ from the equation that you earn on the part of a.</p>

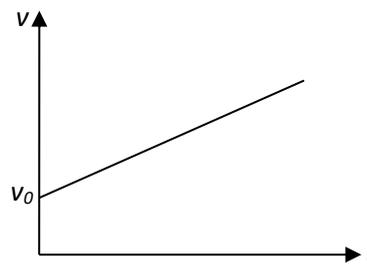
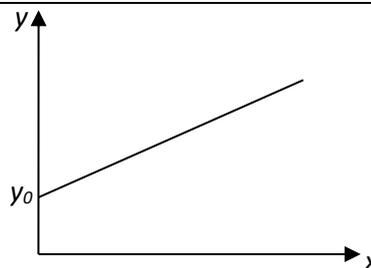


Table 2. Problems of Mathematics and Physics odd semester 2017/2018

Group	Odd semester 2017/2018
P. Mat	Completes the differential equation $\frac{d^2y}{dx^2} = \beta$, β as a constant, with the condition $y = 20$ when $x = 0$
P. Fis	Initially an object at rest, then fell under the influence of gravity of the earth in time t second. Determine the distance (x) by the object by using the equation $\frac{d^2x}{dt^2} = g$ and g is a constant

RESEARCH RESULTS AND DISCUSSION

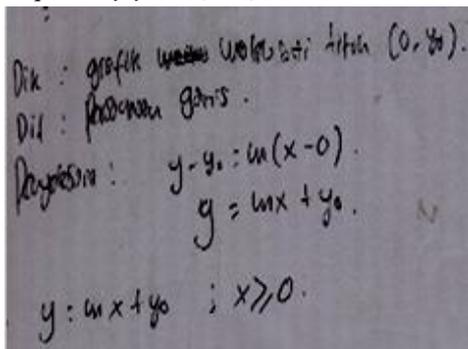
The results of data triangulation ST and SR in the even semester of 2016/2017 showed no consistency in solving P. Mat and P. Fis on two different methods, as well as in the odd semester of 2017/2018 thus be concluded that the second data on the subject are credible, Therefore, the data subject of problem-solving thinking processes are analyzed based on the results obtained only thinking aloud.

Problem Solving ST in Even Semester 2016/2017

Transcript thinking aloud ST when solving problems of Mathematics and Physics in even semester are described with detail in Table 3.

TABLE 3. Results of thinking aloud ST in solving Mathematics and Physics

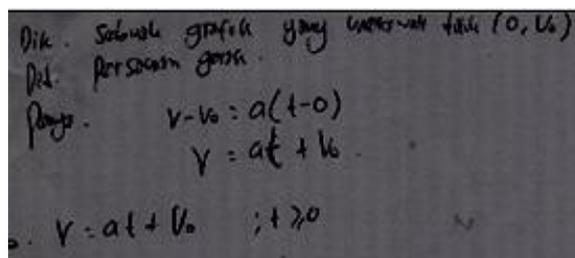
No	Mathematical Problem	No	Physics Problem
P	Before you solve the problem, read the question properly.	P	Before you solve it, read it well the problem!
ST	Yes, ST read all the problem, namely determine the equation of the following chart, What does the graph of the equation means abn get the equation	ST	Read the whole question on the issue. Find the equation of motion of an object that is represented by the following chart, What does the equation of motion
	$g = y_0x + \frac{1}{2}mx^2$ from the equation that you earn. While look at the line graph on a coordinate axis.		$s = v_0t + \frac{1}{2}at^2$ of the graph and get the equation from the equation you earn on the part of a, then paused. While viewing the graphs of motion of an object on the coordinate axes.
P	Continues	P	What do you think
ST	There is a chart (x, y), then asked equation of the graph. The equation of the line of the graph equation of the graph is solved by using the formula of equation of the line with gradient m. This graph through the point (0,y ₀) while viewing the pictures. So, the equation $y-y_0 = m(x-x_0)$	ST	What I was thinking, physics applied mathematics The equation of motion can be determined using a mathematical equation such lines. So the equation through the point (0,v ₀) with the gradient m.



The significance of this graph is the value of $x > 0$, x and y is proportional, if x greater then the value of y is also getting bigger, the interval $x >$

To get the equation $g = y_0x + \frac{1}{2}mx^2$

from $y = mx + y_0$ used integral because here x pointing to parts containing x in the equation are known while in the



Reread the question, "What is the meaning of the equations of motion of the graph" then says "the value of v and t is always positive and so the graph is increasing"

From the part a of a formula before, then I have to get

$$s = v_0t + \frac{1}{2}at^2$$

Based on a graph chart known through the point(0,v₀)

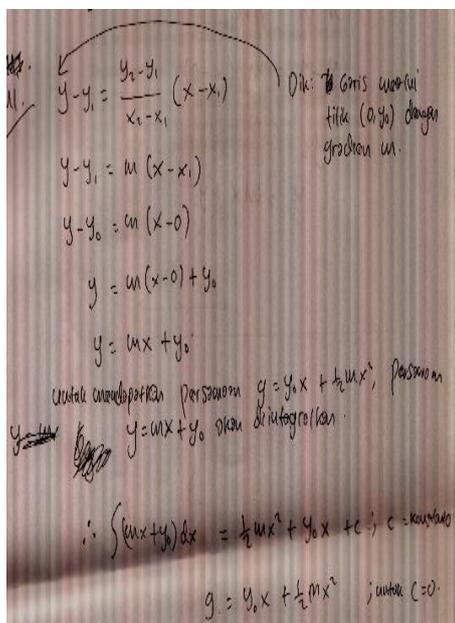
Asked equations of motion are represented by the graph

solved using the equation line $y-y_0 = m(x-x_0)$

Variables v and t replace y and x

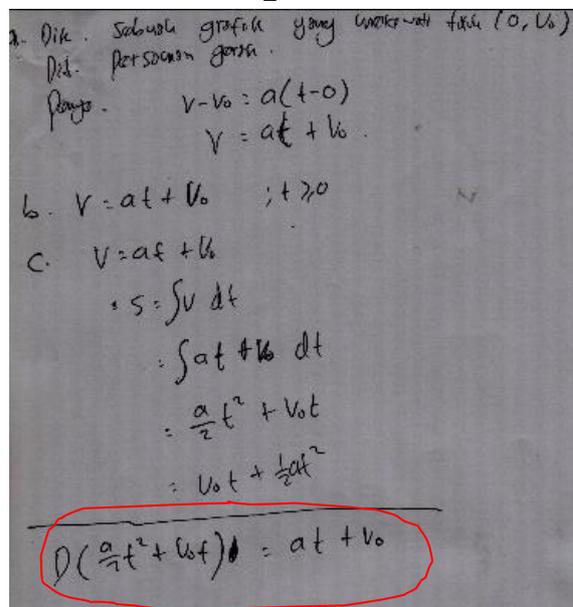
To complete the next process using the way algebra

equation is sought containing x and y_0 in the equation are known while in the equation is sought containing x of y_0 , so as to complete the integral is done. The plan was implemented as follows.



P Why silent
 ST I'm looking for a relationship v and s
 Using Integral with using the speed and position
 To find the formula of a position using integral
 Based on the part a, the formula can be used to obtain

$$s = v_0 t + \frac{1}{2} a t^2$$



P Are you sure with your works.
 ST Reread algorithms work that has been created and mental arithmetic, then say "yes".

P Are you sure with your works
 ST Yes, because after being unloaded equal after been integral

Based on observation, transcripts thinking aloud and interview known that ST understand math and physics problems by reading the whole problem to be solved, and then establish an understanding with repetition reading through graphs, then interpret the information contained on the problem. Yovan (2008) says that repetition can improve recall of information due to the activity of strengthening the relationship between information and more frequent use of the path information, the information on these lines is strengthened in memory. Therefore the problem to be solved with the graphic image, more likely to be on the graph and based on this trying to understand the problem to be solved. This is in line with Rizal & Mansyur (2017), that student mathematics education in understanding the problems tend to pay attention to an image first, read the text a little by little and repeatedly, then as a whole and is more focused on sentences that contain equations, figures or symbols. Based on information obtained through the reading of the graph, it is known that the line through the point $(0, y_0)$ with $x > 0$ and the relationship between x and y is proportional, if x greater then the value of y is also greater in the interval $x > 0$. Then do the interpretation by linking knowledge / experience like ever encountered in planning solution. Ausubel (Novak, 2011) states that the information can be assimilated significantly, if a person can connect with prior knowledge. The same thing also expressed by Gestalt (Hergenhahn and Olson, 2009) that if the environmental aspects were previously unique then found again, so these aspects will not cause an imbalance and will be easily assimilated into the cognitive structure. Based on this knowledge ST planning problem solving math equations using a line through the point $(0, y_0)$ with the gradient m the $y - y_0 = m(x - x_0)$. ST execute according to plan using the formula, so get the equation of the line sought, namely the $y - y_0 = m(x - 0)$ or $y = mx + y_0$. To obtain the equation of the line equation $y = mx + y_0$. ST linking similar experience that have ever found, and comparing tribes known constituent of the equation with the tribes constituent of the equation is sought, thus concluding that resolved with integral.

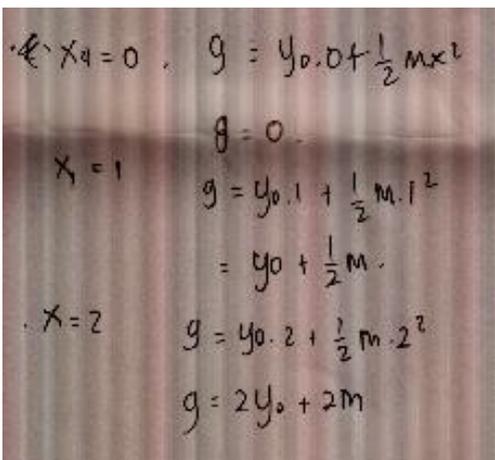
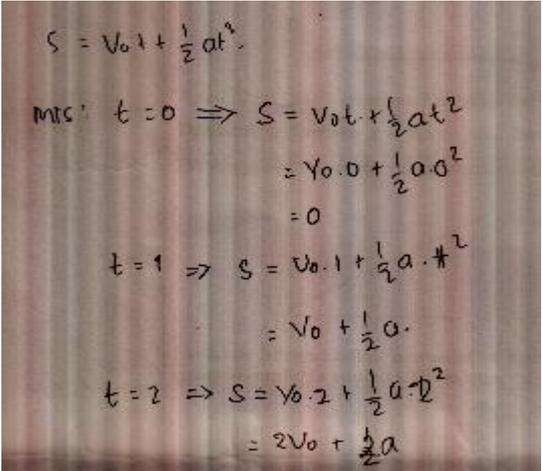
ST in understanding physics problems as well as the when understand the math, that originated from the understanding of the chart, and then interpreting connect mathematical knowledge possessed similar to physics problems faced by the equations of motion can be obtained from the equation of a straight line $y - y_0 = m(x - x_0)$ with the variables v and t replace y and x in obtaining the equations of motion of an object. Additionally ST

knowing that v and t be positive because of the speed and time and the graph is progressively increasing. Based on this interpretation, ST plan to use problem solving equation of the line through the point $(0, v_0)$ with gradient m then, $y-y_0 = m(x-x_0)$. Based on the plan, then the equation of motion of an object is $v-v_0 = a(t-t_0)$ or $v = at + v_0$. At the end of the solution ST examined by reading back the algorithms work that has been created and mental arithmetic. Desoete (2007) that the monitoring skills is an activity monitoring one's cognitive strategies used during the performance of tasks in progress in order to identify problems and modify the plan.

Problem Solving SR in Even Semester 2016/2017

Transcript thinking aloud SR when solving problems of Mathematics and Physics in even semester are described with detail in Table 4.

Table 4. Results of thinking aloud SR in solving Mathematics and Physics

No	Mathematical Problem	No	Physics Problem
P	Before you solve it, first read the question well!	P	Before you solve it, first read the question well!
SR	Trying to understand the overall problem with reading problems, which specify the equation of the graph, what is the meaning of these graphs, doing the interpretation, then get the equation $g = y_0x + \frac{1}{2}mx^2$ from the equation of the line you earn. After reading, then silence and focusing attention on the charts, but can not make sense of and interpret information from graphs.	SR	Understanding the problem by reading repeatedly. "Find the equation of motion of an object that is represented by the chart, Whats the meaning of the equation of motion of the graph and get the equation $s = v_0t + \frac{1}{2}at^2$ from the equation you earn", then a pause and focus attention on the charts
SR	Since it can not make sense so as to create a plan to acquire $g = y_0x + \frac{1}{2}mx^2$ by way of analogy, then substituted to the equation. From the graph shows that if x increases, the value will increases too.	SR	To get $s = v_0t + \frac{1}{2}at^2$ used analogy, then in substitution into the equation. Based on the chart, if the time increases the speed also increases.
SR	Implementing the plan as follows	SR	Implementing the plan as follows
	 <p>Handwritten work for the mathematical problem. It shows the equation $g = y_0x + \frac{1}{2}mx^2$ and its evaluation for $x=0$, $x=1$, and $x=2$. For $x=0$, $g=0$. For $x=1$, $g = y_0 + \frac{1}{2}m$. For $x=2$, $g = 2y_0 + 2m$.</p>		 <p>Handwritten work for the physics problem. It shows the equation $s = v_0t + \frac{1}{2}at^2$ and its evaluation for $t=0$, $t=1$, and $t=2$. For $t=0$, $s=0$. For $t=1$, $s = v_0 + \frac{1}{2}a$. For $t=2$, $s = 2v_0 + \frac{1}{2}a$.</p>
	From this graph, if x increases, then the value is also increase. Here, if $x = 0$, then the value is also 0, if $x = 1$ then the value is also g , and so on.		If $t = 0$, then the speed is also 0 means that the speed fixed (not moving), if the time plus $t=1$, the speed also increases. So, once in the graphic image.
P	Are you sure	P	Done
SR	Review the works that have been created and mental arithmetic, and then say "yes"	SR	Reread the job, then checked by mental arithmetic, and then say "yes".

Based on observation, thinking aloud and interviews showed that the SR in understanding mathematical problems through rereading and reading charts. Information obtained from the graph is not capable of delivering similar linking knowledge ever encountered on the graph. SR are in the condition shown disequilibrium with silence, then repeat reading problems through images, so that eventually can reveal the meaning of the chart, although not perfect, when the value of x increases, the value also increases. Here, if $x = 0$, then its value is also 0, if $x = 1$, then its value is also increase, and so on. Similarly, in understanding the problems of physics, through rereading the SR can reveal the implicit meaning of the graph, when time increases the speed also increases, although this is also not perfect. Based on this insight, SR-solving plan by way of analogy, and substitution value to the equation searched, so the results are not as expected. Hergenhahn and Olson (2009) states that if there is a unique aspect or new of this situation is cannot be responded by previous knowledge, so that, unique or new aspects of this experience will cause a bit of cognitive imbalance (disequilibrium). Yovan (2008) states that repetition can improve recall of information due to the strengthening of the relationship between information activities. Information kept in mind in the form of an information network, so the more frequent use one path information, the information on these lines is strengthened in memory and can easily access the information on the pathway. Furthermore, in examining the results of the work done by counting mentally in accordance with an algorithm that has been done.

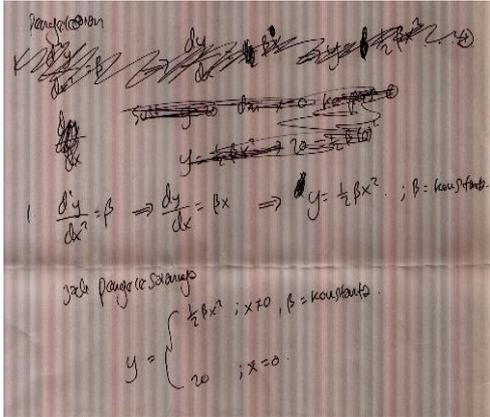
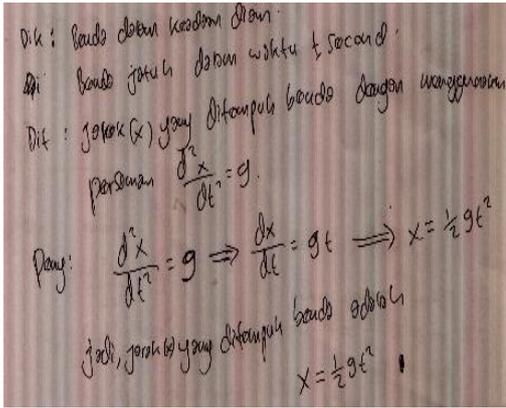
Based on the description above it can be said that the information implicit in the charts have never seen before, but rarely be repeated so that the adjustment scheme which is owned by the information received was very slow to happen. Therefore, the information can be assimilated into the cognitive structure after repeated readings. Piaget (Brooks & Brooks, 1993) says that assimilation is the incorporation of new events into intelligence as a scheme or concept. In assimilation, the stimulus is interpreted based on the scheme which is owned by someone. If the stimulus entered in accordance with the existing scheme, then a person can directly respond to the stimulus. Similar disclosed by Hergenhahn and Olson (2009) that assimilation allows a person to respond to the current situation in accordance with previous knowledge. At the end of the work SR verify jobs that have been created by mental arithmetic. Desoete (2007) that the monitoring skills is an activity monitoring a person's cognitive strategies used during the performance of tasks in progress in order to identify problems and modify the plan.

Problem Solving ST Odd Semester 2017/2018

Transcript thinking aloud ST when solving problems of Mathematics and Physics in odd semester are described with detail in Table 5.

Based on observation, transcripts thinking aloud and interview known that ST understand math and physics problems by reading the whole problem to be solved, and then establish an understanding with repetition readings. This is in line proposed by Yovan (2008) that repetition can improve recall of information due to the strengthening of the relationship between information activity Based on this insight ST planning problem solving by connecting the integral knowledge that has been held. But in implementation, ST does not make the process of integration, but only through mental arithmetic, so the constant C are expected to emerge during the process of integral does not appear. Therefore, ST can not find the results with the specified requirements. To convince the truth of the work that has been made, ST check the truth through mental arithmetic algorithm based on the work that has been done before and at the end of the solution.

TABLE 5. Results of thinking aloud ST in solving Mathematics and Physics

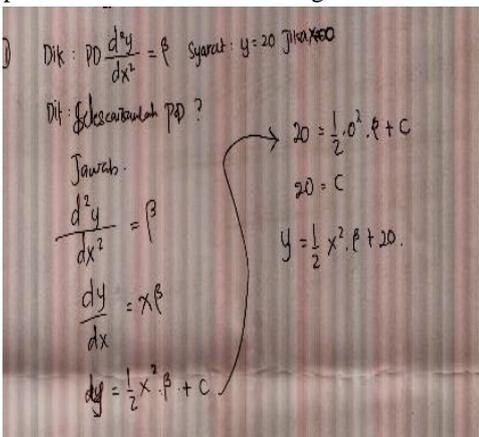
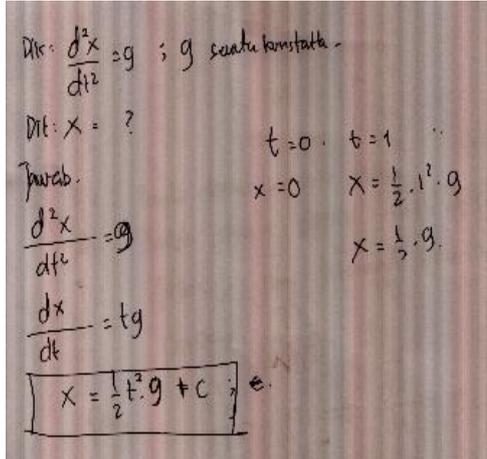
No	Mathematical Problem	No	Physics Problem
P	Before solve it, understand the problem well!	P	Before solve it, understand the problem well!
ST	Complete the differential equations $\frac{d^2y}{dx^2} = \beta$, β , a constant, with the requirement $y = 20$ when $x = 0$ Here will solve differential equations Further resolved by integral twice	ST	Initially an object at rest, then fell under the influence of gravity of the earth in time t second. Determine the distance of the object using the equation $\frac{d^2x}{dt^2} = g$ with g by a constant To determine mileage, used also integral
			
P	Finished!	P	Already convinced of the correctness of the work!
ST	Checking the truth by means of mental arithmetic	ST	Reviewing the work, and then checked by means of mental arithmetic

Problem Solving SR Odd Semester 2017/2018

Transcript thinking aloud SR when solving problems of Mathematics and Physics in odd semester are described with detail in Table 6.

Based on observation, transcripts thinking aloud and interview known that SR understand mathematics and physics are the same problems with the ST, they read the whole problem to be solved, and then establish an understanding with repetition readings. Based on this insight SR planning the problem solving to connect the integral knowledge that has been held. However, in the implementation SR does not perform an integral process, but only through mental arithmetic. This is in line expressed by Ausubel (Novak, 2011) that the information can be assimilated significantly, if a person can connect with prior knowledge. To convince the truth of the work already done, SR check the truth by reading back the work that has been created through mental arithmetic algorithm based on the work that has been created at the end of the solution.

Table 6. Results of thinking aloud SR in solving Mathematics and Physics

No	Mathematical Problem	No	Physics Problem
P	Before you solve it, understand the question well	P	Before solve it, read it well first
SR	known differential equation $\frac{d^2y}{dx^2} = \beta$, with the requirement $y = 20$ when $x = 0$, then asked solve differential equations. This differential equations solved by the integral plan resolved in the following manner	SR	known $\frac{d^2x}{dt^2} = g$ dengan g constant, asked the distance (x) This equation is solved using the integral plan resolved in the following manner
			
P	How, done!	P	Are you confident about the works created!
SR	Search again step by step work that has been done and say "yes".	SR	Reading again the work, then say "yes".

CONCLUSION

Based on the description above it can be concluded that the thinking process of problem solving mathematics education students as follows:

1. The process of thinking of current students understand the problems tend to be the same as the previous semester through repeated readings, write down the information problem to be solved through the images, then do the interpretation of information obtained by linking knowledge / similar experience ever encountered.
2. The process of thinking of students when planning problem solving undergo a process of adaptation of the scheme which has been formed from the stimulus / experiences that prepare solving strategies using the formulas as similar experience I've ever done before.
3. The process of thinking of students when making plans and utilize mathematical knowledge they already had, despite the low math skills can not do it systematically and correctly. In this case, the thought process students undergo a process of adaptation scheme of stimulus received / experience that has been done.
4. The process of thinking of students when checking the truth does not undergo a process of adaptation of the scheme earned experience, students tend to calculate mentally based algorithms and the logic, either before or at the end of the solution.

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