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Student's Understanding of Graph Based on Information-Processing

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Abstract

This study is a preliminary research on how students understand patterns. Students' understanding of something is a cognitive phenomenon as, according to information processing perspective, an integral part of the stimulus, receiving, encoding, storing and retrieving information. This paper aims to describe the information processing by students when they interpret the graph as a task that was delivered using takjil context. There are 9 seven graders aged 11-12 years in various mathematics ability that three students in each its category high, mid and low. It was found that: (1) The graph given in the task attract students' attention with various reasons. (2) The level of abstraction and processing is in accordance with students' mathematical abilities. (3) The number of words related to the context activated at certain period was determined by reviews of their experiences with similar contexts. (4) Concepts of a new schemes were not solely determined by the students' mathematical abilities. Broadly, this study recommends students to have learning experiences through varying contexts and gain extensive experiences to develop appropriate and useful cognitive schemes for solving problems.

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INTRODUCTION

Thinking is an invisible mental activity, yet the thinking result can be a visible activity. From the psychological point of view, we considers thinking as a manipulation of the mental representation of information [1]. Thinking turns a particular information representation into a different new form.

From the perspective of information processing, Siegler states that thinking itself is information processing. Thinking is a memory process which comprises activities of processing, monitoring, setting strategies related to the incoming information [2].

From the constructivism perspective, information processing occurs within active learners. Active learners process information by selecting, maintaining, and transforming the information that generate new knowledge and better skills. Piaget describes this process as an enhanced cognitive scheme, which is a result of the merging of old information and newly received information [2].

In a mathematics context, problem-solving questions are often used to understand the growing cognitive scheme. The question contexts are related to the students' real life. The solving process requires understanding of the problem, knowledge of previously learned concepts or rules, and transformation of the knowledge to make the best solution. The problem solving process reflects the cognitive scheme or the information processing itself.

This study is a preliminary research on how students understand patterns. According to Schacter, educational psychologists believe that memory should not be assessed by how children add something to their memory. Instead, it has to be viewed from how children organize their memory. Most studies on rules application tend to focus on what is used to solve problems instead on how people obtain the rules [3]. This study is in line with most studies as it traces the information processing experienced by some students when they were solving a given task. Finding a cognitive scheme activated during information processing is a challenge to better understand students. This research limits its scope to describing the students' information processing occurring when they expressed their understanding of a problem-solving question related to *takjil* sale. The students participated in this research are differentiated by their mathematical ability: high, mid, and low.

Students' understanding of something is a cognitive phenomenon as, according to information processing perspective, an integral part of the stimulus, receiving, encoding, storing and retrieving information. External stimuli received change to ready-to-process information. Information processing occurring in memory consists of three main stages, namely encoding, storage, and retrieval [2]. Based on the work done by Atkinson and Shiffrin, Lutz and Hiutt developed a stage model of memory that showing information processing occurs in memory[6].

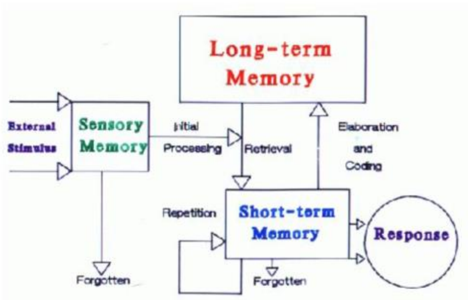


Figure 1. A stage model of memory by Lutz and Huitt (2003)

Stimuli are what someone feels through his or her senses. When one receives tasks through written commands, his or her sense responds by observing. The information received visually is then forwarded to the memory system to be processed.

Sensory memory functions as a memory portal of external information received by the sense organs [4]. Information will go to the short-term memory through the portal if it receives attention or if automaticity occurs. Attention is triggered by relevant experience or sensory-dominated things, such as bright colors, loud sound or voice, or very strong feelings. Information which does not proceed to the short-term memory will be forgotten.

Encoding is the process of entering information to the memory. Siegler (Santrock, 2012:311) states that if related to problem solving, one only encodes the relevant information and ignores the irrelevant one. An encoding process is a process of entering information to the storage. This process, taking place in the short-term memory, sends the information to the long-term memory.

Short-term memory functions as a temporary storage. Repeating information can keep the information in the short-term memory, and meaningful information will proceed to the long-term memory. Giving meaning to information requires an elaborate explanation by means of personal association to the information. Deeper processing of information results in better memory. Deeper processing involves a mental process in giving meaning to information. The deeper the information processing is, the better the memory will be. This suggests that shallow meaning fades the information. Information passed the encoded process will be stored in the long-term memory and can be retrieved when needed.

Short-term memory is not merely a temporary storage. The short-term memory is the working memory since it is here that the information is processed and manipulated to solve problems [4]. Decisions are made by the central executive with the help of visual-spatial working memory and phonological loop. There is an active reciprocal interaction between short-term and long-term memories caused by the transmission process of storing and using information.

According the Piaget's development theory, one will adapt to newly received information. The information adaptation process happens through assimilation and accommodation. If the information has never been received before, a new scheme will be constructed through an assimilation process. A new scheme will also be constructed by accommodating an old scheme. The existence of a new scheme shows that someone has experienced a cognitive development.

Information can stay from few to thirty seconds or even a lifetime. Information only stays few seconds in the sensory memory. This information will either go to the short-term memory or disappear. If the information goes to the short-term memory, better understanding of the information will help send the information to the long-term memory. This suggests that the information will be forgotten if there is shallow understanding of the information.

Information which can enter the long-term memory is the encoded one. This information has transformed into a new scheme. The scheme will undergo changes as a result of the processed new information.

Retrieval is "bringing back" information from the storage. The information which has transformed to a new scheme will be stored in the long-term memory. New information will activate a scheme according to the nature of the information. The activated scheme refers to the retrieval of particular information in the long-term memory such as facts, concepts, principles, rules and their application. If related to physical assignments, the ability of recalling how to do things comes from the procedural memory.

Adaptation to new information does not logically happen in many ways. Briefly processed or incorrectly combined information may potentially lead to an illogical new scheme.

METHOD

The research subjects were nine seven graders aged from eleven to twelve years. The subjects were categorized based on their math ability, that is, high, mid, and low. A valid placement test was employed in the placement process. The research instrument was a worksheet consisting of a question of *takjil* sale profit with a profit sale graph of the fifteen-day *takjil* sale (Figure 2).

Each subject was assigned to interpret the question. Unstructured interviews were employed to obtained additional explanation on the subjects' written answer. The way the subjects explained their understanding, orally or in written, represents their interpretation of the graph. An analysis of the way the subjects interpreted the graph was conducted by using information processing approach, namely, stimulus, encoding, storage, and retrieval.

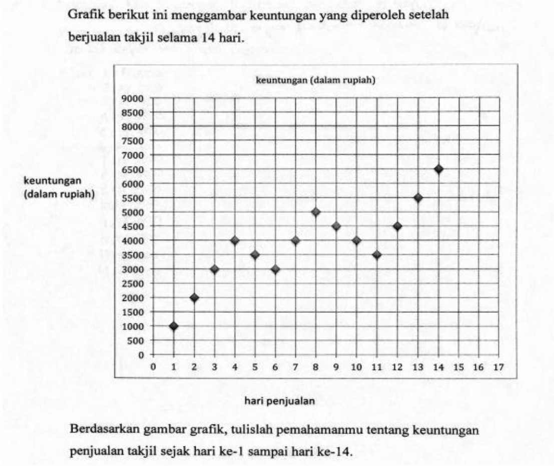
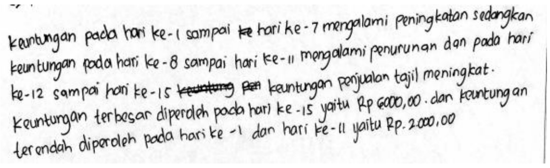


Figure 2. The graph in the question

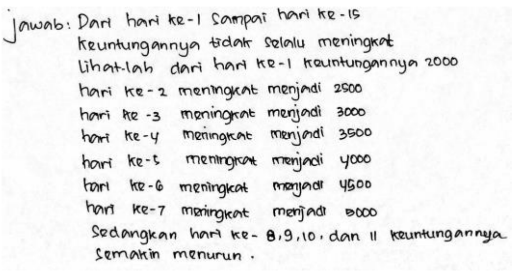
RESULT AND DISCUSSION

An initial was assigned to each subject. An, Fa, Pu were the subjects in the high mathematical ability category; As, Ni, Yu in the mid, and Ci, De, Di in the low one. Data obtained from the subjects' answer were explained based on the stages of information processing, that is, stimulus, encoding, storage, and retrieval. Parts of the subjects' written answer are shown by Figure 3.



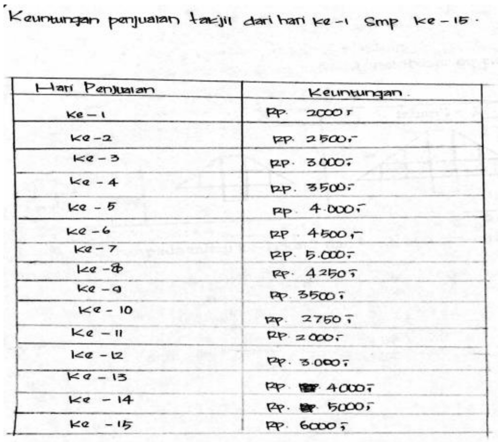
keuntungan pada hari ke-1 sampai ~~ke~~ hari ke-7 mengalami peningkatan sedangkan keuntungan pada hari ke-8 sampai hari ke-11 mengalami penurunan dan pada hari ke-12 sampai hari ke-15 ~~keuntung~~ ~~Pen~~ keuntungan penjualan tajil meningkat. Keuntungan terbesar diperoleh pada hari ke-15 yaitu Rp 6000,00. dan keuntungan terendah diperoleh pada hari ke-1 dan hari ke-11 yaitu Rp. 2.000,00

(a) An's Answer



Jawab: Dari hari ke-1 sampai hari ke-15
keuntungannya tidak selalu meningkat
lihatlah dari hari ke-1 keuntungannya 2000
hari ke-2 meningkat menjadi 2500
hari ke-3 meningkat menjadi 3000
hari ke-4 meningkat menjadi 3500
hari ke-5 meningkat menjadi 4000
hari ke-6 meningkat menjadi 4500
hari ke-7 meningkat menjadi 5000
Sedangkan hari ke- 8,9,10, dan 11 keuntungannya semakin menurun.

(b) Yu's answer



Keuntungan penjualan takjil dari hari ke-1 Smp ke-15.

Hari Penjualan	Keuntungan.
ke-1	Rp. 2000,-
ke-2	Rp. 2500,-
ke-3	Rp. 3000,-
ke-4	Rp. 3500,-
ke-5	Rp. 4.000,-
ke-6	Rp 4500,-
ke-7	Rp. 5.000,-
ke-8	Rp. 4250,-
ke-9	Rp. 3500,-
ke-10	Rp. 2750,-
ke-11	Rp. 2000,-
ke-12	Rp. 3.000,-
ke-13	Rp. 4000,-
ke-14	Rp. 5000,-
ke-15	Rp. 6000,-

(c) De's answer

Figure 3. The subjects' written answers

Stimuli

All subjects visually received the information when reading the question. Although all subjects could read the question well, not everyone directly pictured what answer to write. Ci and Ni were unsure about the word "*pemahamanmu*" [your understanding] in the instruction. Subject Ci asked, "*Apa maksud kata 'pemahamanmu'*?" [What does "pemahamanmu" mean?]. Subject An asked, "*Apa yang harus dikerjakan [sambil menunjuk kata 'pemahamanmu']*?" [What should I do? [while pointing at the word "pemahamanmu"]. At this point, both Ci and Ni were asked to reread the question carefully. Ci's and Ni's doubt indicates that both did not experience automaticity of the word "*pemahaman*" [understanding].

When receiving the question sheet, all subjects paid attention to the graph presenting the profit of the *takjil* sold for fifteen days. Observing questions do not always involve reading questions in order. All subjects stated that they looked at the graph for a while before reading the question in order. While observing the graph, all subjects were attracted to the dots in different positions. They paid less attention to the information on the coordinate system. After they looked at the graph, they read each word and numbers in the graph. They paid more attention to the graph only if they needed to. This suggests that the graph dots in particular positions became the dominant stimuli. This finding is in line with that of Schneider's and

Prerssley's that states that elementary school children remember images better than they do with verbal or written sentences [2].

The analysis also shows that although all subjects had the same sequence of acquiring information, they had different reasons why they chose to look at the graph first. Following part of conversation and their reasoning.

Researcher : Why the graph attract special attention for the first time?
An : graph certainly does represent something
Fa : charts are usually long understood
Pu : usually about summarized in the chart
As : surely the answer will be in touch with chart
Ni : chart will be used when answering the question
Yu : graph should be used (to answer questions)
Ci : the graph is interesting but it is usually difficult (to understand)
De : rarely about who uses charts
Di : chart more attractive than words

The investigation result shows that the subjects with high mathematical ability tended to see the graph as a part of the overall problem. The subjects with mid mathematical ability looked at the graph because they needed it to solve the problem. The subjects with low mathematical ability, however, saw the graph as an interesting thing or different from the rest of the question.

Encoding

Encoding is the process of entering information to the long-term memory. The information recorded through attention or automaticity gets meaning. That is why it can proceed to a more durable memory. The constructed images stay longer if they get meaning. Here, the constructed image is related to the *takjil* context used in the question. The breadth of information network also helps explain the subjects' experience related to the word *takjil*. This breadth of information network is related to the activation of words representing things or events related to the word *takjil.* Some examples of the activated words are *makan* [eat], *makanan manis* [sweet food], *kolak* [a sweet fruity food mixture containing coconut milk], *bubur* [porridge], *jajanan* [snack], *jajanan segar* [refreshing snack], *es* [ice], *gorengan* [fried snack], *sore hari* [evening], *jualan di pinggir jalan* [selling on the street], *pedagang dadakan* [temporary sellers], *berebutan membeli* [race to buy], *puasa* [fast], *buka puasa* [breakfast], *bulan ramadhan* [Ramadhan month], *lebaran* [Eid al-Fitr], *berjualan* [sell], *untung* [profit], *rugi* [loss]. Table 1 shows the number of words representing words or events activated by the subjects within thirty seconds. This table shows that the subjects with low mathematical ability had the tendency to activate more words.

Table 1. Number of words activated

Mathematical ability	Subject	Number of words activated
High	Fa	4
	Pu	5
	An	11
Mid	Ni	3
	As	4
	Yu	11
Low	De	5
	Di	8
	Ci	12

The relationship between *takjil* and the graph also plays a role in deeper information processing. The information processing proceeds from shallow to deep level, depending on how meaningful the received information is. When a subject comprehended the graph, the difference in the information processing depth was shown by the way the subject expressed information of the question. The subjects' understanding of the graph was measured by their written answers which were later clarified through interviews. The measurement results were then used to classify the subjects based on their information processing depth into four categories. The categories are (1) understand the position of each dot; (2) understand the position of each dot and the profit rise/fall based on the previous dots; (3) understand the position of each dot and classify it based on the profit rise/fall; (4) understand the position of each dot, classify it based on the profit rise/fall, and analyze the pattern difference. The explanation below makes use the written answers in Figure 2.

a. Figure 2(a). An was able to understand the dots, compare the pattern differences based on the *takjil* profit rise/fall, and added analysis on the highest and lowest profit. Therefore, the depth of An's information processing is in level 4.
b. Figure 2(b). Yu understood that sales did not always increase. Yu recognized each dot and was able to compare the profit rise/fall in every two consecutive dots. The depth of Yu's information processing is in level 2.
c. Figure 2(c). De understood the meaning of each dot, but did not give more information. The depth of De's information processing is in level 1.

The depth of all subjects' information processing is shown by Table 2.

Table 2. The depth of information processing based on the mathematical ability

Mathematical ability	The depth of information processing			
	(1)	(2)	(3)	(4)
High			Fa, Pu	An
Mid		Yu	As, Ni	
Low	Ci, De	Di		

Table 2 shows that the subjects with higher mathematical ability tend to process information more deeply. These subjects are able to understand abstract concepts better and have the tendency to holistically interpret the graph to compare inter-group patterns. The subjects with mid mathematical ability partially interpret the graph based on the groups of the same pattern. The subjects with low mathematical ability understand each graph dot and make comparison from consecutive dots. This concludes that the levels of abstraction and processing are in accordance with the students' mathematical ability.

Elaboration is a key to permanently storing information in a way that facilitates its quick retrieval when it is needed [6]. The elaboration of *takjil* context understanding, mathematical understanding, and the combination of both produce a new understanding of the question's graph. Differences in the subjects' question interpretation both orally and in written represent the subjects' information organization of the question given. Therefore, each subject has had a new scheme when expressing his or her understanding of the question's graph.

Storage

The organization of the question is stored in the long-term memory to be recalled when needed. The in-depth interview was conducted to find out the result of elaborated understanding of the *takjil* sale profit, the mathematic concept, and the concept application when understanding the graph. The analysis result of the students' understanding of the graph shows that:

a. the subjects with high mathematic ability think formally and holistically. Graphs are the centers of interpretation and the image patterns on graphs tell something about the context. Graph images are examples of how contexts transformed into mathematical forms. Therefore, the question's fluctuating graph image from one point to another or from one group to another explains the fluctuating variability of the sale profit.
b. the subjects with mid mathematic ability partial and concrete way of thinking. Profit becomes the key to all explanation. Patterns are recognized in terms of both units and groups. In this question, the subjects thought that profit could be big, small, rising, or falling. Total profit can be calculated.
c. the subjects with low mathematic think in concrete units. Profit is also the key to all interpretation. Patterns are recognized in terms of units. In this question, the subjects thought that profit could change either increase or decrease.

Retrieval

The use of *takjil* conteks, graphs, and task the question can activate a long-term memory scheme which is strongly connected to the information. Activated schemes are information with the most attention. This scheme is processes and organized in the short-term memory. Information organization and decision making are done by the executive memory and this produces a new scheme.

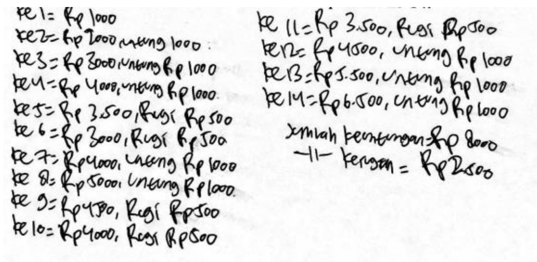
When the subjects received a stimulus through a problem solving question containing a graph, they could select the scheme to activate. Table 1 shows the number of *takjil*-related words recognized by the subjects. This table shows that the subjects with low mathematic ability tend to have more of *takjil*-related vocabulary. However, the number of activated words is not in line with the depth of information processing as shown by Table 2. An, Yu and De, who have the most activated word networks in each mathematic level category, do no posses the same level of mathematic ability. This shows that the subjects with high mathematic ability do not retrieve more information when interpreting the graph.

In constructing a new scheme, not all subjects could correctly organize the information. In addition, errors may happen in combining pieces of old and new information. Two subjects, De and Fa, experienced this error. They activated an understanding which was different from what was expected. De's statement "*harga takjil berbeda-beda tergantung isinya apa*" [*takjil* prices varies depending on its content] and Fa's interpretation "*menurun adalah negatif, berarti tidak bisa untung*" [decreasing means negative, no profit whatsoever] confirm that the *takjil* prices dominated De's thought and a memory of negative gradients dominated Fa's thought.

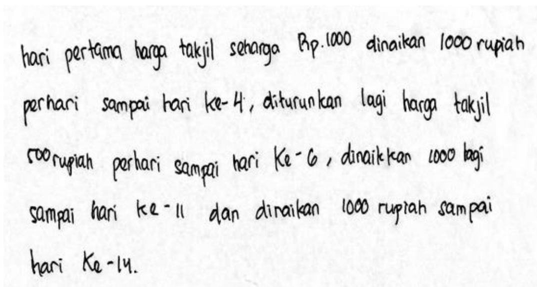
Errors made by Fa and De are presumably from the incorrect combination of old and new schemes. In one interview session, Fa read, gave meaning to each graph dot, and wrote "*pada hari ketiga terdapat keuntungan sebesar tigaribu rupiah, ... pada hari kesembilan terdapat keuntungan sebesar tigaribu limaratus rupiah...*" [On the third day, there was a three thousand rupiah profit, . . . , on the ninth day, there was a three thousand five hundred rupiah profit]. This sentence shows Fa could actually interpret each graph dot correctly. However, Fa's statement "*kan kalau makin ke kanan makin turun berarti negatif...*" [if it's getting lower when it gets to the right side, it means negative] is an evidence that a memory or negative gradient dominated Fa's understanding on the graph.

In one interview session, De stated "*oh... ternyata saya salah tulis. Maaf, seharusnya keuntungan (bukan harga) takjil*" [I've made a mistake. Sorry. It was supposed to be *takjil* profit not *takjil* price]. This means that De was aware of the error in the written statement, and De understood how to correct the error.

These two errors conclude that retrieval is not determined by the first stage of information processing. Instead, it is determined by stronger information related to the keyword network. Misleading may occur as a result of error in transforming information to the memory scheme.



(a) Fa' answer



(b) De' answer

Figure 4. Errors in constructing a new scheme

Errors occurring during the information retrieval may come from the steps of information processing. Improper encoding may cause misled new schemes. This means a dominant thing has distracted the subjects' understanding, which led to the graph misinterpretation. There were two subjects who constructed illogical new schemes. For De, the *takjil* sale profit was the *takjil* price. Although De possessed quite wide information network of *takjil*, De was unable to make a new logical scheme As a result, De considered the *takjil* sale profit as the *takjil* price and the *takjil* fluctuating sale profit was considered as the unstable *takjil* price. This error was possibly caused by De's inability to understand profit graphs and De's automation in remembering prices when reading the sales. So, the error made by De indicates the error in the encoding

Unlike De, the error made by Fa was related to the mathematical concept of the graph. Fa considered less profit as loss or negative income. This interpretation is far from the possibility of understanding of potential loss. It may be caused by Fa's automation in considering declining positions as negative positions. Thus, Fa's error is related to a scheme in the storage.

CONCLUSION

Information processing is caused by stimuli received by the senses. These stimuli are encoded, and then sent to the memory to be retrieved when necessary. In interpreting the given graph, the *takjil*-theme framework could help all subjects understand the question. All subjects could interpret the given graph. The interpretation variation is determined by old information, whose dominant parts may mislead the process. It was found that: (1) The graph on the question attracts students' attention for different reasons, (2) The levels of abstraction and processing are in accordance with students' mathematical abilities, (3) The number of context-related words activated at certain period was determined by the subjects' similar experience, and (4) The concepts of the new scheme were not solely determined by the students' mathematical abilities

This is an ongoing study. Some issues such more varied graphs and information retention have not been addressed. This research recommends that students need to have more and various problem solving activities so that they can be connected to many things in solving problems and can possess the ability of retrieving the correct information. Problem solving activities can be an entrance to understanding mathematical concepts and their real-world applications.

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