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Students' Behavioral Patterns in Solving Ill-Structured Problems

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This study aims to describe the behavioural patterns of high school students when solving ill-structured problems based on a behaviour perspective. This is qualitative research with an exploration approach involving 36 students of the 11th science class. Students were asked to think aloud to solve ill-structured problems with discounts. During the process of problem solving, recorded student behaviour was then described and analysed when solving problems. The results showed that there are two behavioural patterns in solving ill-structured problems: (a) Intuitive behaviour (giving direct answers), which has two subcategories known as proficient and not proficient intuitive behaviour; and (b) analytics, which bring out ideas and manipulate numbers or operations to produce solutions. Three subcategories of analytic behaviour are analytics involving numbers, variables, and combinations between numbers and variables. These study results indicate a difference in student behaviour patterns when solving ill-structured problems. Students' conceptual and procedural knowledge influence this behaviour.

Keywords: *Behaviour, Intuitive, Analytics*

Introduction

The ability of mathematical problem-solving is one of the capabilities that students must be able to manage (NCTM, 2000). Mathematical problem-solving consists of "problem-solving" as cognitive behaviour and "math" as an object. In problem-solving, students are taught to gather facts, analyse information, compile solutions, and choose the most effective strategy. Students are required to make decisions, think critically, and think creatively while solving problems (Hussin, Harun, & Shukor, 2019; Woolfolk, 2009). The abilities to survive and compete require problem-solving skills in the era of globalisation and free trade.

Problem-solving is often found in the form of solving well-structured problems. These issues demand a breakdown process. Consequently, when students are faced with solving ill-structured problems, they can experience confusion. In the learning process, the teacher rarely teaches students to solve ill-structured problems (Hong, 1998; Muhtarom, Juniati, & Siswono, 2017). However, in daily life situations, there are many problems involving ill-structured issues (Hong & Kim, 2016; Hong, 1998).

An ill-structured problem is an unstructured problem involving a complex process of solving. It is not clearly defined, open, and affects the real world. In ill-structured problems, some aspects of a situation are not conveyed, not even containing information that helps the problem-solving process (Chi & Glaser, 1985). The complexity of unstructured problems can pose difficulties for students in regulating problems and monitoring the process of finding solutions. Students often have a slight misunderstanding or conception of domains and fail to control their understanding and progress. This can impede their success in solving problems. Solving ill-structured problems involves four key processes: (a) problem representation, (b) develop solutions, (c) make justifications and construct arguments, and (d) monitor and evaluate problem-solving plans and solutions (Ge & Land, 2003, 2004).

In this study, the ill-structured problems given were not clearly defined problems. There was missing information from a given problem, so it demanded problem solvers to develop strategies to find a solution. The described student behaviour solves the problem of some researchers by examining the verbal protocols of the students' behaviour when solving arithmetic problems (Hegarty, Mayer, & Monk, 1995; Niederhauser, Ogilvie, & Toy, 2013). Student reasoning behaviour regards the difficulties of understanding integers and metacognitive behaviour is involved in solving the problem. Problem-solving behaviour is reviewed (from successful and unsuccessful problem-solvers) based on the meaningful behaviour (Abdullah et al., 2018; Demircioğlu, Argün, & Bulut, 2010; Padang, Fuad, & Ekawati, 2018). Problem-solver behaviour is reviewed in terms of the auditory learning style. Behaviour regards problem-solving stages' planning and a problem solving strategy (Sardi, Rizal, & Mansyur, 2018;Wahyudi, Subanti, & Usodo, 2018). Based on previous studies on student behaviour, there is no research discussing students' behaviour in solving ill-structured problems.

The study has the purpose of reviewing and describing the behaviour of high school students in solving ill-structured problems from a behavioural perspective. The aspect of behaviour refers, in this case, to summarising and transforming sentence structure to have a better understanding and planning in problem-solving (Pape, 2004).

Based on the perspective of the behaviour allows misunderstanding, including language, failed in translating(Pape, 2004; Yang, Li, & Xing, 2018). Besides, a lack of adequate conceptual knowledge or mathematical procedural, the inability to coordinate the essential knowledge structures to solve problems, inadequate reading strategies, and establishing a solving strategy. The right problem also becomes a perspective in this study.

Research Problem

Student behaviour that solves a problem is a significant factor of success, especially when solving ill-structured problems, but no research has been discussed. Therefore, the problem in this study is "What are students' behavioural processes like in solving ill-structured problems, particularly on the issue of double discounts?".

Method

Research Design

This is a qualitative study using a descriptive exploratory approach. It aims to explore the behaviour of students in solving ill-structured problems regarding a double discount. This study has the purpose of describing, analysing, and interpreting individual behaviours in problem-solving.

Participants

This study was conducted with students of 11th sciences high school in Surabaya, East Java, Indonesia. 36 science students were involved in this study, and the student demographic structure is presented in Table 1.

Table 1. Participants' Demographic Structures

Class	Aspects	N
Gender	Male	12
	Female	24
Age	15-16 years old	8
	16-17 years old	26
	≥18 years old	2
Department	Sains	36
Culture	Javanese	34
	Maduranese	2

Data Collection

Before the study data was collected, researchers trained students to think aloud during the learning process. Students were prepared for three months to use think aloud in problem-solving. The goal was for students to become accustomed to using think hard about problem-solving involving double discounts. The researchers provided target math problems for students. While they were solving problems, researchers recorded the results of the students' work and observed the interesting things that students did. Based on student work, thinking aloud, and observation, researchers clarified things that were unclear through semi-structured interviews with students.

Data Collection Tools

The data collection tools used in this study were ill-structured problem (ISP) exercises and targets. ISP exercises consist of two practice issues, while the target ISP consists of one problem for each topic. One of the ISP exercises involved increasing the length and width of a rectangle in the form of percentages, while the target ISP was a double discount issue. The target problem that researchers used in this study was adapted from the NCTM (2008) as follows:

> "A pair of shoes in Sogo and Matahari have the same price. Sogo gives a discount of 50%, then 30%, while Matahari gives a discount of 70%. Which store do you think gives the most discounts?"

Data Analysis

The data analysis phase is done by describing student behaviour, classifying data that leads to research findings, and drawing conclusions. In the first stage, the behaviour of students in problem-solving was described. Then, behavioural patterns were categorised into intuitive categories and an analytics category. Students were said to be in an intuitive category if and only if they provided a direct solution and were spontaneous in solving the problem. Students were said to be in the category of analytics if and only if, in the process of solving problems, they worked step by step to find a solution. The final stage draws conclusions based on findings, classification results, and data presentation.

Procedure

Students were given ISP exercises three times each for 30-45 minutes for a think-aloud held over three months. During the training process, a researcher's assistant reminded students to get used to revealing what they think. For example, when reminding students to read aloud, the assistant researchers said, "Please read in a loud voice." In this way, the experiment sought to accustom students to thinking hard so that the researchers could know the slightest change in behaviour.

After the practice of thinking aloud, each student was recorded individually in a separate room of their class (e.g., in a library or science lab) in November and December. Each student was given 30-45 minutes to crack the target ISP. During the breaking of the target ISP, the researchers recorded hard thought performed by students. Based on student work and thinking aloud, the researchers described student behaviour when solving problems.

Students' behavioural recordings were classified into discrete behaviours, indicating their behaviour when solving problems, such as when students read or reread sentences. The researchers will describe only audible readings. Other behaviours are noted, including gestures that indicate clues to the problem text without audible indications, audible or unheard calculations (e.g. written work), statements from answers, final answers, and other direct quotes. The next step is classifying them into student behaviour in intuitive and analytical categories.

Results and Discussion

From the descriptive results of the behaviour, student work can be classified into a student behavioural pattern category when solving ill-structured problems as follows:

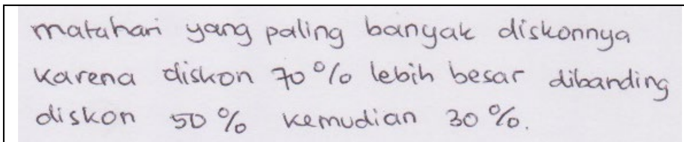
Intuitive Categories

Students are said to be in the intuitive category if and only if directly providing a solution and being spontaneous in solving the problem. In this case, a student immediately gives the final answer by giving reasons without offering evidence. In this intuitive category, there are two subcategories of student behaviour when solving ill-structured problems:

Proficient Intuition

Students automatically give the final answer without counting the process. Students have the final answer and reasons appropriately without providing proof of counting. Examples of students' works in the intuitive right category are shown in Figure 1.

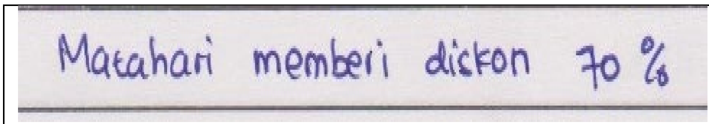
Figure 1. Students' Work: Proficient Intuition

	Translate Version
 matahari yang paling banyak diskonnya karena diskon 70% lebih besar dibanding diskon 50% kemudian 30%.	Matahari gives the most discounts because 70% greater than the discount 50% then 30%.

Un-proficient Intuition

Students automatically give the final answer without counting the process. Students provide the final answer, do not give an reason, and do not provide evidence of counting. Examples of students' works in an intuitive, not proficient category can be seen in Figure 2.

Figure 2. Students' Work: Un-proficient Intuition

	Translate Version
 Matahari memberi dickon 70 %	Matahari gives discount 70%

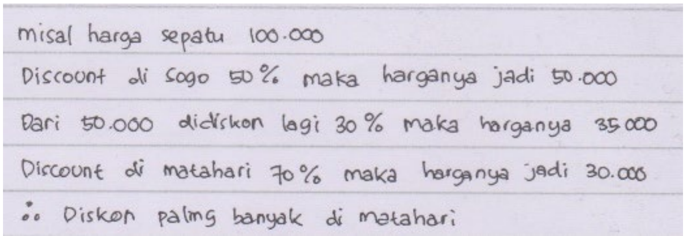
Analytics Categories

Students are said to be in the analytics category if and only if solving the problem step by step until finding the final answer. In this case, a student gives an idea that helps them with problem-solving. There are three subcategories of students in this category:

Analytics Using Numbers

Students bring up ideas that help them solve problems using the price of shoes, for instance. Then, students perform the counting process that ends with the decision making, which is the final answer. Figure 3 shows examples of student work in this category.

Figure 3. Students' Work: Analytics Using Numbers

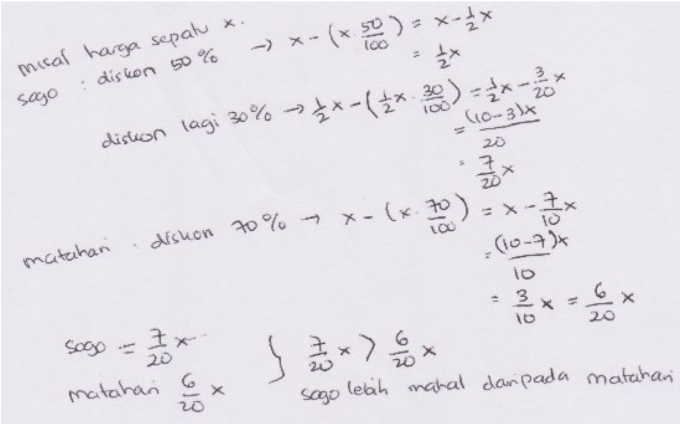
	Translate Version
 misal harga sepatu 100.000 Discount di Sogo 50 % maka harganya jadi 50.000 Dari 50.000 didiskon lagi 30 % maka harganya 35.000 Discount di matahari 70 % maka harganya jadi 30.000 ∴ Diskon paling banyak di matahari	Suppose the price of shoes 100,000 Sogo discount 50% the price to 50,000 Then, discount 30% from 50,000 price to 35,000 Matahari discount 70% the price to 30,000 So, Matahari the greatest discount

Analytics Using Variables

Students bring up an idea that helps solve a problem using variable partitioning (regarding the price of shoes, in this instance). Afterward, students perform a counting process using that variable, which ends with the decision-making (the final answer). Examples of students' works in the variable analytics category can be seen in Figure 4.

Figure 4. Students' Work: Analytics Using Variables

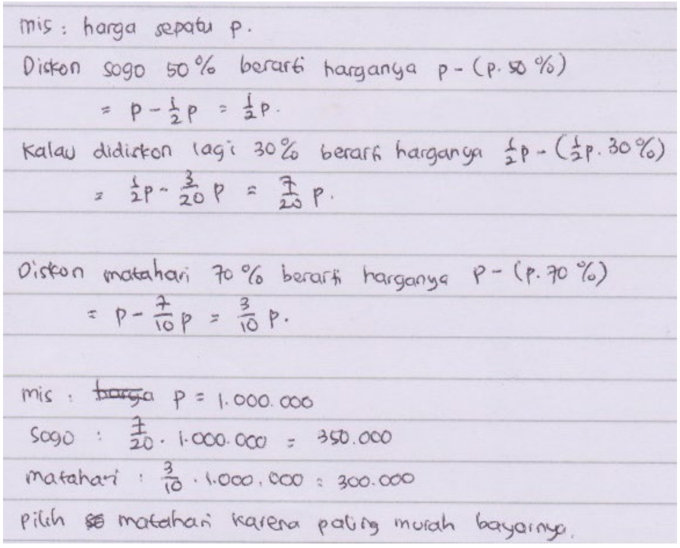
Translate Version

	Suppose the price of shoe x Sogo: discount 50% →$x – (x.\frac{50}{100})$ $= x - \frac{1}{2}x = \frac{1}{2}x$ then discount 30% →$\frac{1}{2}x – (\frac{1}{2}x.\frac{30}{100})$ $= \frac{1}{2}x - \frac{3}{20}x = \frac{(10-3)x}{20} = \frac{7}{20}x$ Matahari: discount 30% →$x– (x.\frac{70}{100})$ $= x - \frac{7}{10}x = \frac{(10-7)x}{10} = \frac{3}{10}x = \frac{6}{20}x$ Sogo = $\frac{7}{20}x$ } $\frac{7}{20}x > \frac{6}{20}x$ Matahari = $\frac{6}{20}x$ Sogo more expensive than Matahari

Analytics Combination

In analytics combination, students bring up ideas that help them solve the problem of using variable partitioning of the price of shoes and validated using the number of shoes. Then, students perform the counting process that ends with the decision making, which is the final answer. Here are examples of students' works in the combination analytics category, as seen in Figure 5.

Figure 5. Students' Work: Combination

<table>
<tr><td></td><td>Translate Version</td></tr>
<tr><td>
</td>
<td>Suppose the price of shoes p
Sogo discount 50% the price
$p – (p.\ 50\%) = p – ½\ p = ½\ p$
Giving more discount 30% the price
$½\ p – (½p – 30\%) = ½\ p - \frac{3}{20} p\ \ \frac{7}{20} p$

Matahari discount 70% the price
$p – (p.70\%) = p - \frac{7}{10} p = \frac{3}{10} p$

Suppose p = 1.000.000
Sogo: $\frac{7}{20}$. 1.000.000 = 350.000
Matahari: $\frac{3}{10}$. 1.000.000 = 300.000
We choose Matahari because cheaper paid</td></tr>
</table>

Based on the results of the students' behaviour records and their work on solving ill-structured problems, there are two categories of behavioural patterns. The use of video data allows the researchers to describe students' behaviour precisely in solving ill-structured problems (Hegarty et al., 1995; Niederhauser et al., 2013; Ozturk & Guven, 2016). Behaviours in this study include student behaviour in the category of intuition and analytics. Students are said to be in the category of intuition if they give the final answer quickly and spontaneously (Fischbein, 1999). The answers that students give can derive from previous knowledge relating to the double discount issue. This condition does not correlate with the possibility of the results of trial and error or those suspected by students (Avdiji, et al., 2018).

Students of this category have confidence in correct answers given even if the evidence is not given. There are two categories of students who are in the intuitive category, i.e. (1) proficient intuitive students, who give correct answers to a given problem, and (2) un-proficient intuitive students, who provide the wrong answer to a given question. Students do not provide evidence of the solving process but give the reason the answer is given. Students with confidence have an ability in the problem-solving process involved in finding a solution (Hong, 1998; Muhtarom et al., 2017; Ozturk & Guven, 2016). Subjects believe the truth, their answers are gained based on the relevance of the concepts used, and the answers make sense in the context of the initial problem.

A student in the un-proficient category is intuitive; a student makes the error of translating the keyword "then". Students make errors in interpreting the concept of actual discount pieces. Errors translating keywords are one of the language weaknesses that students have in this category (Nusantara & Chandra, 2016; Pape, 2004; Prayitno, et al., 2018; Rachmawati, Sugandi, & Prayitno, 2019; Sukoriyanto, et al., 2016; Yang et al., 2018). Therefore, keyword usage is a vital component in the problem solving process (Anwar, et al., 2016; Hussin et al., 2019; Yang et al., 2018).

Students are said to be in the analytical category if in the process of solving problems using a step by step process of problem solving. As stated by Subanji & Nusantara (2016), the analytic approach is a complex process of resolving issues into parts to ease a problem solver in finding solutions. Students with good problem-solving skills will divide into parts to find a solution. In this study, students are said to be in the analytical category if they bring out ideas and manipulate numbers or operations to produce solutions that lead to the final answer. This is analogous to the process of solving the problem, which uncovers information that supports the problem-solving process (Abdillah, 2017; Abdullah, et al., 2017). The appearance of this idea is not easy because students are required to use critical thinking in the problem solving process to determine a useful strategy (Woolfolk, 2009).

Based on the results of students' work, some students use the appropriate method but make errors in the process of counting results (Abdullah et al., 2017; Paradesa, 2018). The errors involve calculating percentages due to the obscurity of the basic percentage idea that students understand. Therefore, students need to understand the concept of percentages as both have roles in daily life. This study concerns whether or not a student is familiar with the concept of percentages such as 25%, 50%, and 100%, and understand their meaning, so further study needs to be done (Hussin et al., 2019; Paradesa, 2018). Besides, strategies used to solve complex problems such as ill-structured problems are among the success factors in problem solving (Balta & Asikainen, 2019).

Findings indicate there were students who succeeded and did not succeed in solving ill-structured problems. This is where self-regulation plays an important role when dealing with problem solving tasks. Students with self-reliance in learning can regulate and control the problem solving process (Zimmerman & Campillo, 2003). This applies to students who have a high, self-regulated tendency to be able to monitor, regulate, and evaluate effective processes. Literature suggests that self-regulation is an important component to metacognitively involve a period of problem solving rather than only the phase of operating in monitoring and evaluation (Zimmerman & Campillo, 2003). The work was an attempt to understand the interactive relationships between self-regulation and ill-structured problem solving, yet it does not clearly or explicitly address the interrelationship between two important processes (Ge & Land, 2003; Ge, Law, & Huang, 2016).

Solving a complex problem requires more knowledge. In addition, it requires motivation and a personal ambition to face challenges and survive until reaching a desired solution (Kazemi, Fadaee, & Bayat, 2010; Zimmerman & Campillo, 2003). In the process of solving ill-structured problems, teachers play an important role in teaching problem solving skills to their students integrally. It is expected that by learning this problem-solving process, students will be accustomed to using the concept of knowledge in problem solving (Hong, 1998; NCTM, 2000). The way teachers solidify their skills in solving problems is not by focusing on the final answer only. In this case, teachers should also focus on the solving strategy used along with the reason to try a specific strategy (Muhtarom et al., 2017). The implementation of learning or cooperative learning is needed.

Conclusion

The results of this study on student behaviour and ill-structured problems, especially regarding the double discount issue, belong to the categories of intuition and analytics. The intuitive category is based on the direct answers that students give without giving evidence. There are two subcategories of intuitive behaviour: (a) proficient intuitive and (b) un-proficient intuitive. Students of the proficient intuitive category are students who answer directly, correctly and with no evidence. Meanwhile, the students of the un-proficient intuitive category are the students who have the wrong answer and provide no evidence.

The students of the analytics category are students who solve the problem step by step. There are three subcategories of analytic behaviour: analytics involving numbers, variables, and combinations. The students in the analytic category (including involving numbers), can solve using the price. The students of the analytics category are concerned with variables; students bring out the price of an item using a x as a variable. Students in the combination analytics category are students who bring out the price of an item using a variable. In certainty, students replace the variable with a certain number.

Declaration of Conflicting Interests

The author(s) declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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