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ANALYSIS OF STUDENTS' INCORRECT ANSWERS IN A MATHEMATICAL TEST: AN INSIGHT ON STUDENTS' LEARNING BASED ON SOLO TAXONOMY AND ERROR ANALYSIS

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ABSTRACT

Students' incorrect answers in a mathematics test provide insight into their mathematical ability and can be used as a foundation to formulate effective countermeasures. Thirty students' answers in a mathematical test were analyzed, and students with the highest rate of incorrect answers were interviewed individually to delve further on circumstances that contributed to their results. Results suggested that 45.8% of students made varying degrees of mistakes in answering the questions, with five students performing the poorest. Inadequate understanding of mathematics concepts and students' disposition contributes to students' incorrect answers.

Keywords: error analysis; SOLO taxonomy; mathematics; problem-solving

ABSTRAK

Jawaban yang salah dalam tes matematika memberikan wawasan tentang kemampuan matematika siswa dan dapat digunakan sebagai dasar untuk merumuskan tindakan pencegahan yang efektif. Jawaban 30 siswa dalam tes matematika dianalisis dan para siswa dengan tingkat jawaban salah paling tinggi diwawancarai secara individual untuk mempelajari lebih lanjut tentang keadaan yang berkontribusi pada hasil yang mereka peroleh. Hasil penelitian menunjukkan bahwa 45,8% siswa membuat berbagai tingkat kesalahan dalam menjawab pertanyaan, dengan lima siswa memperoleh capaian paling buruk. Pemahaman konsep matematika yang kurang memadai dan disposisi siswa berkontribusi terhadap jawaban salah.

Kata kunci: analisis kesalahan; Taksonomi SOLO; matematika; *problem-solving*

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INTRODUCTION

Biggs and Collis (1982) stated that learning should meet both the quantity of learning (how much has been learned) and the quality of learning (how well it has been learned) and that there are stages in the growth of learning. In essence, they argue that there should be a distinction between cognitive structure of an individual and the structure of the actual responses to specific tasks at a particular time. By shifting the focus to how students responded to a task and if the particular answer is classified, then the teacher can compose a strategic approach to act on it. Such classification is the basis of the Structure of the Observed Learning Outcomes (SOLO) Taxonomy. SOLO Taxonomy consists of prestructural, unistructural, multi structural, relational, and extended abstract stage (Biggs and Collis, 1982; Biggs and Tang, 2011). SOLO Taxonomy depicts two primary learning goals: increasing knowledge (quantitative: from unistructural and becoming more multi structural) and deepening understanding (qualitative: relational then extended abstract) (Biggs and Tang, 2011). Since its introduction in 1982, SOLO Taxonomy has been successfully used in recent efforts for assessing learning outcome across discipline (Chan, Tsui, Mandy, Hong, 2002; Minogue and Jones, 2009; Newton and Martin, 2013; Stoyanovich, Gandhi, and Flynn, 2015) and used as a basis for suggesting reform in teaching and learning process.

In making a strategic approach to act on how students' responded to a particular learning task which in turn can reform the teaching and learning process, the approach can be based on incorrect responses or what defined as mathematical errors. Radatz (1980) summarized that analyzing errors can be used to develop criteria for

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differentiating mathematical education program, create awareness and support for the students, and clarify some fundamental questions of mathematics learning. Movshovitz-Hadar, Zaslavsky, and Inbar (1987) further argued that error analysis is useful for teachers, curriculum developers, and researchers to diagnose as well as remediate and eliminate students' mathematical errors. Deconstructing students' errors can also offer mathematics educators a practical instructional strategy for reforming mathematics teaching and learning (Borasi, 1994). In her review, Ben-Zeev (1998) explained that mathematical errors are often consistent rather than random so that it presents an opportunity for revealing underlying mathematiccal reasoning. Aside for the educators, analyzing problems can also help the students recognize their misunderstandings in mathematics (Lim, 2014).

Previous studies have evaluated mathematics learning through the lense of SOLO Taxonomy (Chick, 1998; Chan et al., 2002; Ekawati, Junaedi, and Nugroho, 2013; Ozdemir and Yildiz, 2015) or based on students' error (Isgiyanto, 2011; Subanji and Nusantara, 2013) but unfortunately studies evaluated mathematics learning through the lense of SOLO Taxonomy and based on students' errors is still limited. Therefore, in this study, mathematics learning was evaluated based on SOLO Taxonomy as well as students' errors so that the root cause of students' errors can be identified.

METHOD

The study was conducted in one of junior high schools in Semarang, Central Java Province, Indonesia. Sample was thirty eight grade students. To evaluate students' understanding of geometry, students were given a test (essay) consisted of five questions (reasoning, problem solving, representation, communication, and connection) based on SOLO Taxonomy level (Biggs and Collis, 1982; Biggs and Tang, 2011). To understand the cause of mathematical errors, observation and interview sheets were used to probe students' disposition towards mathematics. Students' errors was based on several errors' classifications (see Newman, 1977; Radatz, 1979; Movshovitz-Hadar et al., 1987, Table 1).

Table 1. Type of Mathematical Errors and its Indicators

Type of Error/Difficulties	Indicators
Mathematical Comprehension (C)	A student's mathematical comprehension is insufficient in which he/she lacked the knowledge about content, concepts, symbols, and problem-specific expertise. Having a distorted understanding of a specific principle, rule, theorem, or definition which resulted in the incorrect application of the mathematical procedure, technique, rules, formula, or strategy.
Misusing Data (D)	Inadequate understanding of the stated facts or misusing the given data.
Semantic Difficulties (S)	Students are having difficulties in understanding the semantics of mathematical text in which they found problems in understanding natural or mathematical language or in translating natural language into a mathematical expression.
Technical Error (T)	Student making calculation or technical error

Table 2. Students' Answers for Test Questions based on SOLO Taxonomy (n=30)

Question	Mathematical Process Standard	SOLO Taxonomy Level	Correct Answer		Incorrect Answer	
			Total	%	Total	%
1	Reasoning and Proof	Relational (R)	18	60	12	40
2	Problem solving	Extended Abstract (E)	11	37	19	63
3	Communication	Relational (R)	15	50	15	50
4	Representation	Relational (R)	23	77	7	27
5	Connection	Extended Abstract (E)	14	47	16	53
		Average		**54.2**		**45.8**

Table 3. Students' Answer according to SOLO Level and Errors Found in Their Answer

Question, MPS, and SOLO Level	Respondent S-01	S-03	S-04	S-16	S-24
Question I **Reasoning and Proof** **Relational (R)**	**Respondent SOLO Level:** Unistructural (U) **Type of Error :** (C) Incorrect Understanding of the question itself (C) Incorrect use of mathematical strategy (I) Incorrect solution	**Respondent SOLO Level:** Unistructural (U) **Type of Error :** (C) Incorrect use of mathematical strategy (S) Error in translating question to a mathematical language	**Respondent SOLO Level:** Unistructural (U) **Type of Error :** (C) Incorrect use of mathematical strategy (S) Error in translating question to a mathematical language	**Respondent SOLO Level:** Relational (R) ---	**Respondent SOLO Level:** Unistructural (U) **Type of Error :** (C) Incorrect Understanding of the question itself (C) Incorrect use of mathematical strategy (I) Incorrect solution
Question 2 **Problem solving** **Extended Abstract (E)**	**Respondent SOLO Level:** Unistructural (U) **Type of Error :** (C) Incorrect use of mathematical strategy and algebraic procedure (D) Misusing the given data (S) Error in translating question to a mathematical language (I) Failed to arrive in a solution**.**	**Respondent SOLO Level:** Unistructural (U) **Type of Error :** (C) Incorrect use of mathematical strategy, rules, formula and algebraic procedure. (D) Misusing the given data (S) Error in translating question to a mathematical language (I) Failed to arrive in a solution**.**	**Respondent SOLO Level:** Unistructural (U) **Type of Error :** (C) Incorrect use of mathematical strategy and algebraic procedure (D) Misusing the given data (S) Error in translating question to a mathematical language (I) Failed to arrive in a solution**.**	**Respondent SOLO Level:** Multistructural (M) **Type of Error :** (C) Incorrect use of mathematical strategy and algebraic procedure. (D) Misusing the given data (S) Error in translating question to a mathematical language	**Respondent SOLO Level:** Unistructural (U) **Type of Error :** (C) Incorrect use of mathematical strategy and algebraic procedure. (D) Misusing the given data (S) Error in translating question to a mathematical language (I) Failed to arrive in a solution**.**
Question 3 **Communication** **Relational (R)**	**Respondent SOLO Level:** Unistructural (U) **Type of Error :** (C) Incorrect use of mathematical strategy and algebraic procedure (D) Misusing the given data (I) Failed to arrive in a solution**.**	**Respondent SOLO Level:** Unistructural (U) **Type of Error :** (C) Incorrect use of mathematical strategy and algebraic procedure (D) Misusing the given data (I) Failed to arrive in a solution**.**	**Relational (R)** -----	**Respondent SOLO Level:** Unistructural (U) **Type of Error :** (C) Incorrect use of mathematical strategy and algebraic procedure (D) Misusing the given data (T) Making calculation error (I) Incorrect solution**.**	**Respondent SOLO Level:** Unistructural (U) **Type of Error :** (C) Incorrect use of mathematical strategy and algebraic procedure (D) Misusing the given data (I) Failed to arrive in a solution**.**

Table 3.(continued)

Question, MPS, and SOLO Level	Respondent S-01	S-03	S-04	S-16	S-24
Question 4 **Representation** **Relational (R)**	**Respondent SOLO Level:** Multistructural (M) **Type of Error :** (T) Calculation error (I) Incorrect solution	**Respondent SOLO Level:** Unistructural (U) **Type of Error :** (D) Misusing the given data (T) Making calculation error (I) Failed to arrive in a solution.	**Respondent SOLO Level:** Unistructural (U) **Type of Error :** (C) Incorrect use of mathematical strategy, rules, formula and algebraic procedure (D) Misusing the given data (T) making calculation error (I) Failed to arrive in a solution.	**Respondent SOLO Level:** Unistructural (U) **Type of Error :** (C) incorrect use of mathematical strategy, rules, formula and algebraic procedure (D) Misusing the given data (T) making calculation error (I) Failed to arrive in a solution.	**Respondent SOLO Level:** Unistructural (U) **Type of Error :** (C) Incorrect use of mathematical strategy, rules, formula and algebraic procedure (D) Misusing the given data (T) Making calculation error (I) Failed to arrive in a solution.
Question 5 **Connection** **Extended Abstract (E)**	**Respondent SOLO Level:** Multistructural (M) **Type of Error :** (D) Misusing the given data (T) Making calculation error (I) making unverified solution i.e. solution presented is not an answer to the given problem	**Respondent SOLO Level:** Unistructural (U) **Type of Error :** (S) Error in translating question to a mathematical language (T) Making calculation error (I) making unverified solution i.e. solution presented is not an answer to the given problem.	**Respondent SOLO Level:** Multistructural (M) **Type of Error :** (D) Misusing the given data (S) Error in translating question to a mathematical language (I) making unverified solution i.e. solution presented is not an answer to the given problem.	**Respondent SOLO Level:** Multistructural (M) **Type of Error :** (D) Misusing the given data (T) making calculation error (I) making unverified solution i.e. solution presented is not an answer to the given problem	**Respondent SOLO Level:** Multistructural (M) **Type of Error :** (C) incorrect use of mathematical strategy, rules, formula and algebraic procedure (I) making unverified solution i.e. solution presented is not an answer to the given problem
Number of errors	4 Comprehension Error 3 Misusing Data 1 Semantic difficulties 2 Technical Error 5 Inference Error	3 Comprehension Error 3 Misusing Data 3 Semantic difficulties 2 Technical Error 4 Inference Error	3 Comprehension Error 3 Misusing Data 3 Semantic difficulties 1 Technical Error 3 Inference Error	3 Comprehension Error 4 Misusing Data 1 Semantic difficulties 3 Technical Error 3 Inference Error	6 Comprehension Error 3 Misusing Data 1 Semantic difficulties 1 Technical Error 5 Inference Error

Note : Mathematical Process Standard (MPS), Comprehension Error (C) 19 errors, Misusing Data (D) 16 errors, Semantic difficulties (S) 9 errors, Technical Error (T) 9 errors, and Inference Error (I) 20 errors with total of 73 errors.

RESULTS AND DISCUSSION

Based on students' answers data (Table 2), the highest correct answer was found for representation questions (SOLO-relational level, 23 students, 77%), while the highest incorrect answer was found for the problem-solving item (SOLO-extended abstract level, 11 students, 63%). These results suggested that the students were able to work on the representation question relatively well but having considerable difficulty in working on the problem-solving question. Gagatsis and Shiakalli (2004) study found that the success of mathematical problem-solving influenced by a majority of interacting factors in which Lai, Zhu, Chen, and Li (2015) study found that factors within the students' such as anxiety and metacognition are factors influencing students' success in problem-solving. To understand the cause for errors in solving mathematical problems, we analyzed and interviewed five students' categorized as students with high incorrect answers (S01, S03, S04, S16, and S24).

A collective 73 errors was found from the five students (Table 3), with three types of errors namely inference error (27.4%), mathematical comprehension (26%), as well as misusing data (21.9%) as prominent types of mistakes. In contrast, semantic error (12.3%) and technical error (12.3%) occurrence were comparatively lower. The presence of technical error or semantic difficulties can be considered as typical for word problems in which Jitendra and Kameenui (1996) study showed that these types of challenges were found even in someone categorized as experts in mathematics. Movshovitz-Hadar et al. (1987) also found a high occurrence of errors due to mathematical comprehension and misusing data. Still, contrary to this study result, inference errors in their study had the lowest occurrence. Errors' categorization in Movshovitz-Hadar et al. (1987) study were also adopted in our study, but a possible difference in terms of the type of questions leads to contrasting results. Their data were derived from students' errors in several mathematics topics: logarithm, geometry, trigonometry, quadratic functions, probability, and series. This study was based on errors in geometry question only so that differences in question specificity resulted in a different result.

There were five students performed the poorest in answering the test in which all five students failed to reach extended abstract level. S01 and S24 incorrectly answered all five questions in which they were only able to reach uni structural to the multi structural range with a tendency toward uni structural level (Table 3). S04 and S16 reached a relational level for one of the questions, but both made substantial errors (13 errors for each students) in the other four questions. Conceptual understanding is essential for solving mathematical problems in which an inadequate understanding of the concept made learners unable to solve problems in different contexts (Hutapea, Suryadi, and Nurlaelah, 2015). In the interview, we found statements such as "*I don't understand all of the test questions because it is so difficult*" or "*I'm confused, which formula I should use because there are so many new formulas I recently learned.*" These statements indicate that students experience difficulty in the adjustment process that involves replacing or changing the scheme because new information is not in accordance with their existing knowledge scheme. In terms of geometry as concept tested in this study, previous result also corroborated the findings in which Isgiyanto (2011) found that conceptual errors was the highest type of errors in students' geometry test answers.

Statements such as "*...it is so difficult*" also reflected students' confidence in solving the given problems. Personal judgment of one's ability to perform specific tasks in specific situations is defined by Pajares and Miller (1994) as self-efficacy. Self-efficacy plays an essential role in achievement in which it serves as a predictor in mathematical problem-solving success (see Pajares and Miller, 1994; Pajares and Kranzler, 1995; Pajares and Miller, 1995). Studies further found that self-efficacy was a significant predictor of problem-solving accuracy and efficiency (Hoffman and Spatariu, 2008; Hoffman, 2010). Therefore, students' self-distrust of their own ability resulted in their inability to solve the problems or solve them correctly. Aside from self-distrust statements, the interview also revealed a complete distrust of the benefit of doing mathematics, as showed by S-24's interview transcript.

Q : *Why were you unable to solve every questions correctly?*
S-24: *I dislike mathematics (subject)*
Q : *Why?*
S-24: *I'm too lazy to do it. It is complicated and make me dizzy.*

Previous studies indicated that attitude or disposition towards mathematics correlated with mathematical achievement (Hemmings, Grootenboer, and Kay, 2011; Mata, Monteiro, and Peixoto, 2012; Mullis, Martin, Foy, and Arora, 2012), in which students' with a positive attitude towards mathematics tends to have better achievement. S-24 showed a negative attitude towards mathematics, which unfortunately resulted in his poor performance in solving the questions (he made the highest number of errors, 16 errors in total, Table 3) ranging from conceptual to inference errors.

Negative attitude and expectations, as well as exposure to a condition deemed unfamiliar or overly complicated (Onwuegbuzie and Wilson, 2003) or unfamiliarity with solving mathematical problems within a particular time constraint (Ashcraft and Moore, 2009) could trigger anxiety in doing mathematics. This condition was found in S-16, who made a total of 14 errors mostly in terms of misusing the data. When asked why she did not write every known facts or data correctly, she said: "*because there is a time (constraint), so that I can finish it (the questions) quickly*". The feeling of having to solve the problems quickly led her to make errors, which resulted in incorrect answers for four out of five questions given. This study results corroborated previous findings that anxiety negatively affecting mathematics achievement (Legg and Locker, 2009; Ramirez, Gunderson, Levine, and Beilock, 2013; Ramirez, Chang, Maloney, Levin, and Beilock, 2016; Novak and Tassell, 2017).

Anxiety due to time constraints could also related to the high occurrence of students' inference errors in this study. Subanji and Nusantara (2013) stated that errors in making correct inferences resulted from the disconnection between mathematical concepts within their minds when constructing the answer and insufficient time for reflection. In this study, students with a high number of errors overly aware with time constrain so that they did not have time to check on and reflected on what they wrote on their answers sheet. The time given to do the test was a regular and typical length for a test with five questions, but the anxiety level in these five children was probably far higher than their peers so that their anxiety due to time constraints resulted in a high rate of mathematical errors.

Interview results showed that an inadequate understanding of mathematics concepts, and students' disposition contributes to students' incorrect answers. Assessing students' conceptual understanding is then essential because it can unravel students' characteristics so that teachers can effectively devise an orderly plan for improving learning. This study, though small in sample size, indicates that understanding students' characteristics, i.e., students' understanding and disposition towards mathematics can be regarded as the first step to create a better learning environment and improve achievement.

CONCLUSION

Students made a varying degree of mistakes in answering the questions based on SOLO Taxonomy, with five students performed the poorest. Inadequate understanding of mathematics concepts and students' disposition contributes to students' incorrect answers. Teachers' awareness of these circumstances is vital in creating fruitful and meaningful learning.

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