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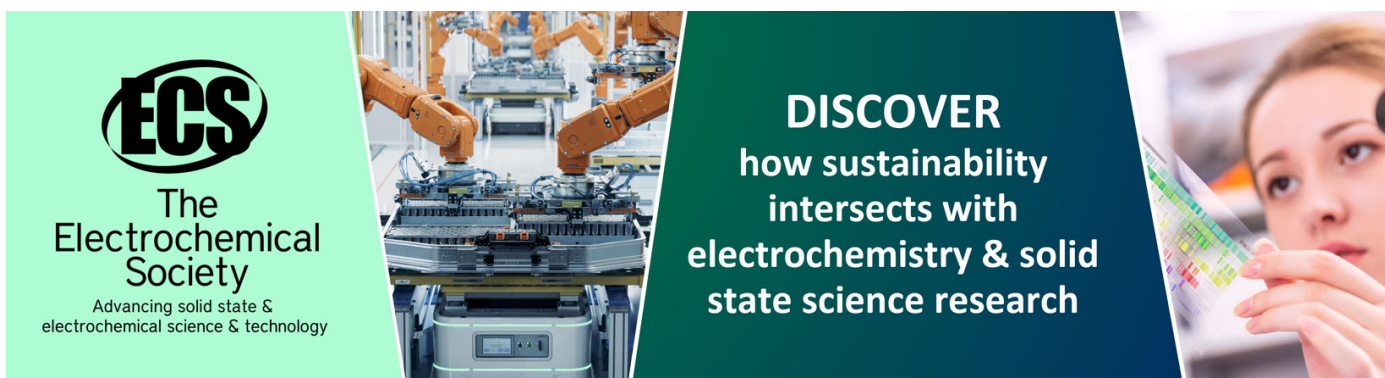
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An analysis of students' mathematical reasoning ability in statistic problem solving based on structure of the observed learning outcome taxonomy

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Abstract. This research was done to describe students' ability toward mathematical reasoning in solving statistics test within mean material based on *structure of the observed learning outcome* (SOLO) taxonomy. There were two participants in this research who have the highest score and the average score. This research was used descriptive qualitative. The collecting data in this research were got from students' answer sheets and interview. Each question in the test was made based on the indicator in stages of SOLO taxonomy. The interview guidelines used in this test was adapted from the list of questions in Newman analysis procedure. The collected data were analyzed by using qualitative analysis technique, particularly the model of interactive analysis technique. The result shows that the high achiever student stands in the extended abstract stage in SOLO taxonomy when solving the statistics test within mean material, meanwhile the other student belongs to the multi-structural stage of SOLO taxonomy when solving the question about mean.

1. Introduction

In the last 2015, Indonesia officially becomes the member of ASEAN Economic Community (AEC) which will continue for the next years ahead [1]. Related to the labor market, AEC surely pushes the flow of human resources to get through the market competitively. Education is the investment in human resources development, because education helps somebody to get many experiences and have well-managed life goals. Education will produce the excellent human resources if the learning process is effective enough. Mathematical reasoning is one of the standards which should be common for the students in mathematics learning process [2]. The standard process in mathematics learning are 1) knowing that mathematical reasoning is important, 2) creating and analyzing mathematical assumption, 3) developing and evaluating mathematical statement and its evidence, 4) choosing and using the types of mathematical reasoning [3].

In formal educational process of Indonesia, students' learning outcomes must be treated through evaluation process. It relates to the regulation in Indonesian's minister of education and culture number 104 in 2014 about evaluating students' learning outcomes in elementary school and high school [4]. Arikunto argues that evaluation is the process of assessment by measuring first [5]. That is why, that evaluation process is useful for analyzing the skills which have been understood by the students and the skills which have not been. One of those skills is students' 'mathematical reasoning.



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This evaluation process will be useful to determine what things should be improved in learning process in order to develop students' mathematical reasoning ability. It is in line with the regulation from government number 32 in 2013, about the national standard of education which implies that evaluation is done to improve learning process [6].

Moreover, Bigs and Collis in Potter & Kustra investigate student's learning outcomes in part of cognitive based on Structure of the Observed Learning Outcome (SOLO) taxonomy [7]. This SOLO taxonomy has five stages based on the structure of students' response. It includes Prestructural, Uni-structural, Multi-structural, Relational, Extendedabstract [8].

1. Prestructural: in this stage the students tend to use incorrect and irrelevant information to solve the problems [9]. Presuctrural stage is also called as pre-learning stage. The students do not have enough information and understanding which are used to build the comprehension structure.
2. Uni-structural: in this stage, the students have had the correct and relevant information based on the problems, but still limited [10]. The students only have one particular concept and they do not have knowledge to relate that concept with the other concepts.
3. Multi-structural: in multi-structural stage, the students have had the correct and relevant information and they also can build the basic connection with the other relevant concept [11], although the students still do not know that there is connection between the concepts.
4. Relational: this stage shows that there is a whole comprehension in the form of integration between knowledge and the relevant concept. The students can see how some different concept can build the wider and more complex meaning [11].
5. Extended-Abstract: this stage is the highest stage in SOLO taxonomy. Extended-abstract illustrates the understanding of concept which is wider than the integration of the concept itself. It refers to the understanding of the whole concept which involves connection and the concept structures, those concepts are usually relevant and applied in the wider context [8].

Looking from the list of core competence and standard competence in high school curriculum asserted by the regulation of education and culture minister number 24 in 2016, one of the material got by the third grade students in high school is statistics [12]. Statistics is the material which will be learned by the students until they study in college and even in their workplace. That is why, it is important to measure students' reasoning ability in solving statistics questions, in this case *mean* material, based on the stages of SOLO taxonomy.

2. Method

This research was done based on descriptive qualitative research. There are two participants who were randomly selected from the third grade of MTs 1 Malang, they are SE and SI. Based on their grade in the fourth semester, SE got 97, categorized as the high achiever student and SI got 75, categorized as average achiever student. This category was made based on Truman Kelley's experience in Susetyo about grouping the students based on their score [13]. The best ability got by the students was: 27% high score group, 27% low score group and 46% got the average score.

The researcher used some instruments such as written test and interview. The written test used in this research was students' reasoning analysis test in solving some statistics questions which about mean material. This test contained of one problem with four questions. Each question was used to measure students' reasoning ability in the stages of SOLO taxonomy. These are the exam content outline of students' reasoning ability test in answer the questions about mean based on SOLO taxonomy stages:

Table 1. The exam content outline of students' reasoning ability test in answer the questions about mean based on SOLO taxonomy

Code of stages	No of questions	The exam content outline of SOLO taxonomy	The exam content outline of students' reasoning in the stages of SOLO taxonomy
U	1	The students are able to explain the correct statement based on one of information in the test.	1. The students are able to determine the order of value by checking the pattern and detect the order of value ratio correctly.
M	2	The students are able to explain the correct statement based on the connection of some information in the test.	1. The students are able to determine the order of value by checking the pattern and detect the order of value ratio correctly.
R	3	The students are able to determine the ratio of the number of students between two classes correctly.	1. The students are able to make generalization about the order of ratio on mean to determine the ratio of students in the two classes correctly. 2. The students are able to determine the relationship of number of students between the two different classes correctly. 3. The students are able to recheck their answer correctly.
E	4	The students are able to determine the new mean of the whole class, if they are given the new mean from the other class.	1. The students are able to develop generalization which is got before to determine the mean for the whole classes if they are given the new mean from the other class. 2. The students are able to determine the relationship of amount of students in the class with the mean correctly. 3. The students are able to determine the relationship of amount of students between two different classes correctly. 4. The students are able to recheck their answer correctly.

(Source: adapted from Potter [7]; NCTM [3])

Notes:

U : Uni-structural stage

M : Multi-structural stage

R : Relational stage

E : Extended Abstract stage

The interview used in this research was adopted from interview procedure of Newman [14]. It refers to the research experience done by Saleh who analyzed the process of students' reasoning during solving the problem based on Newman procedure [15]. The researcher interviewed the participants in order to confirm the process of students' reasoning based on their answer in the answer sheet. These are the outline of interview in students' reasoning:

Table 2. The Interview guideline for students' reasoning process.

Newman	The question outline
Reading skill	Is there any symbols or words that you do not understand in the test?
Comprehension skill	What information did you get from reading the questions in the test? Are you sure?
Mathematical transformation skill	Tell me how you get the idea of solving the questions! What makes you difficult to answer the questions? Are you sure with your answer?
Process skill	Give your explanation about how you count before! What makes you difficult to do it?
Encoding	Tell me how you decide your final answer! Are you sure with your final answer?

(source: adapted from White [14])

The data collection was analyzed by using qualitative analysis technique with the model of interactive analysis technique. Based on the students' answer in the interview, reasoning ability of the two participants were described based on the stages of SOLO taxonomy, so that the researcher can categorize the reasoning ability of participants in solving the statistics questions based on the stages of SOLO taxonomy. The students would be categorized in one of the stages in SOLO taxonomy if they have all the skill or indicators in SOLO taxonomy stages.

3. Result and Discussion

These are the result of students' reasoning test analysis based on the stages of SOLO taxonomy like in the following table 3:

Table 3. The result of students' reasoning test analysis based on the stages of SOLO taxonomy

Code of stages	students' reasoning indicator based on the stages of SOLO taxonomy	SE	SI
U	The students are able to determine the order of value by checking the pattern and detect the order of value ratio correctly.	√	√
M	The students are able to determine the order of value by checking the pattern and detect the order of value ratio correctly.	√	√
R	The students are able to make generalization about the order of ratio on mean to determine the ratio of students in the two classes correctly.	√	√
	The students are able to determine the relationship of amount of students between two different classes correctly.	√	
	The students are able to recheck their answer correctly.	√	
E	The students are able to develop generalization which is got before to determine the mean for the whole classes if they are given the new mean form the other class	√	
	The students are able to determine the relationship of amount of students in the class with the mean correctly	√	
	The students are able to determine the relationship of amount of students between two different classes correctly.	√	
	The students are able to recheck their answer correctly	√	

Notes:

U : *Uni-structural stage*M: *Multi-structural stage*R : *Relational stage*E : *Extended Abstract stage*

Based on the Table 3, the result reveals that SE is able to require all indicators of mathematical reasoning based on SOLO taxonomy stages. SE is able to determine the value order by checking the pattern and detect the order of one or more ratio, even SE develop the generalization which was got before to determine the new mean for the two classes correctly. This is the answer of SE for question number 4:

Mean for the test score in class A is $\bar{X}_A$ and class B is $\bar{X}_B$. After getting the final score of two classes, the combined mean is $\bar{X}$. If $\bar{X}_A : \bar{X}_B = 30 : 45$ and $\bar{X} : \bar{X}_B = 7 : 9$. Then answer this question:

4 If mean for class A is multiplied by 3 then plus 5 is equal to 185 and mean for class C is 75. Determine combined mean for three classes (Class A, B, C)!

1

combined mean = $\frac{\bar{X}_A + \bar{X}_B + \bar{X}_C}{A + B + C}$

2

$A = 3x + 5 = 185$
 $x = 180/3$
 $x = 60$

$C = \frac{y}{15} = 75$
 $y = 75 \times 15$
 $y = 1125$

3

$\bar{X}_A : \bar{X}_B = 30 : 45$
 $\downarrow \times 2 \quad \downarrow \times 2$
 $60 : 90$

$\bar{X} : \bar{X}_B = 7 : 9$
 $\downarrow \times 2$
 $14 : 18$

$\bar{X}_A : \bar{X}_B = 60 : 90$
 $\bar{X} : \bar{X}_B = 14 : 18$

$\bar{X}_A : \bar{X}_B = 10 : 15$
 $\bar{X} : \bar{X}_B = 7 : 9$

Amount of data = mean
 Number of data inversely proportional

4

$\bar{X} = \frac{2175}{30} = 72.5$

Figure 1. SE's answer for question number 4

The interview result researcher (Re) with SE is like in the following,

- Re : What information you got when you read question m=number 4?
- SE : Em, if mean for class A times 3 then plus with 5 is 185. Then mean of class C is 75.
- Re : How many students in class C?
- SE : Oh ya, 15 students.
- Re : Is that all? is that all you got?
- SE : Em, wait a minute, let me find the answer for mean of the three classes.
- Re : Ok, explain to me how you get the answer!
- SE : The mean of the score divided with number of the data, so this is the answer (showing the answer of no 1).
- Re : How did you get the number of data in class A, B, and C?
- SE : From here (showing the concept of mean she got).
- Re : What do x and y stand for? (pointing the answer number 2)
- SE : x is the mean of class A, and y the amount of students in class C.
- Re : How did you get the mean of class B and amount of students in class A and B?

SE : I found the mean for class A is 60, so from the ratio I got the mean for class B becomes 90. I used the same way with question number 3, so I got the data in class A is 10 and class B is 5.

Re : Are you sure?

SE : (recheck her answer) Sure.

Based on the interview and SE's answer, it can be described that in picture, symbol no 1, SE could make generalization to determine the mean by dividing amount of data with number of students. Then SE was able to develop that generalization to determine the new mean if she was given the mean form another class. Symbol no 2 reveals that SE was able to determine relationship between amount of students with mean of that class and determining the relationship of amount of students from two different classes. Moreover, symbol no 4 shows that SE could check her answer correctly. The ability to describe the answer can be seen from the interview. Based on SOLO taxonomy by Biggs and Coills someone who stands in Extended abstract stage has characteristic of capability till making connection of some relevant concepts to solve the problems out of the earlier context [8]. It means, SE belongs to extended abstract stage.

Besides, SI is able to determine the score order by checking the pattern and detect the order from one or more than one ratio correctly. However, SI has not been able to determine the ratio of amount of students from two different classes correctly. SI's answer is like in the following:

Mean for the test score in class A is $\bar{X}_A$ and class B is $\bar{X}_B$. After getting the final score of two classes, the combined mean is $\bar{X}$. If $\bar{X}_A : \bar{X}_B = 30 : 45$ and $\bar{X} : \bar{X}_B = 7 : 9$. Then answer this question:

2 Rita argues, "Mean for class A ($\bar{X}_A$) more than combined mean for two class ($\bar{X}$)". Is Rita's opinion correct? Write the proof / reason for your opinion!

I think, Rita's opinion is incorrect. As we can see from the ratio $\bar{X}_A : \bar{X}_B = 30 : 45$ and $\bar{X} : \bar{X}_B = 7 : 9$ or $\bar{X} : \bar{X}_B = 35 : 45$, so $\bar{X}_A : \bar{X} = 30 : 35$. It can be concluded that combined mean for two class more than mean for class A. 1

3 Determine the ratio of the number of class A students' with class B students'!

$\bar{X} = \frac{A \cdot \bar{X}_A + B \cdot \bar{X}_B}{A + B}$ 2

$35 = \frac{A \cdot 30 + B \cdot 45}{A + B}$

$7 = \frac{6A + 9B}{A + B}$

$7A + 7B = 6A + 9B$

$A = 2B$

$1 : 2$ 3

So, the ratio of the number of class A student's with class B student's is $A : B = 1 : 2$

Figure 2. SI's answer for question number 2 and 3

This is some interview researcher (Re) with SI,

Re : Can you tell me how to answer question number 3?

SI : I use this way (pointing the answer in symbol number 2)

Re : Explain to me that way, what do you mean by A,B?

SI : A is amount of students is class A, B is amount of students in class B, X_A is mean for class A, X_B is mean for class B.

Re : And then?

SI : Em, oh ya X is the mean for the whole classes.

Re : Which classes?

SI : Class A and B.

Re : Are you sure?

SI : (recheck her answer) Yes, I'm sure.

Re : Can you tell me how you got the ratio is 1:2 (pointing the symbol number 3)

SI : First I got $A=2B$ it means $A=1$ and $B=2$, so the ratio is 1:2
 Re : See again, which one has more data? A or B?
 SI : (thinking) I think B, B has 2, so, it is true that the ratio is 1:2
 Re : So, your answer is correct?
 SI : Heheh I'm not sure.

Based on the answer sheet and interview with SI, it reveals that, symbol number 1 in the picture shows that SI was able to determine the order of score by paying attention to the two ratios of some scores. Symbol number 2 reveals that SI wrote the formula of generalization of mean of the two classes, but in the interview session, SI cannot explain the formula he wrote before to determine the ratio of the two different classes. Then, symbol number 3 shows that SI was not able to recheck his answer correctly. It is caused by SI did not understand the connection of students amount between two different classes. It also reveals from interview session that SI thought that $A = 2B$ within A is 1 and B is 2, so the the ratio of class A and B is 2.

Based on SOLO taxonomy by Biggs and Coills, someone who stands in multi-structural stage, can have focus more than one concept, then he or she is also able to build the simple connection between those concepts [8]. However, she or he has not understood the relationship between those concepts. It means, based on SOLO taxonomy, SI has been able to build connection between two ratios of some scores, however SI did not understand the relationship of concepts in amount of students from two different classes. So, SI is in the stage of multi-structural.

An interesting finding is found on the answer sheet of SI. Symbol number 2 (Figure 2) reveals that average achiever student able to make a generalization of orderliness average score between classes to define the rasio of the number of studens between two different classes. This thing indicated that average achiever student has already able to to fulfil the first indicator of mathematical reasoning based on SOLO taxonomy on relational stage. But, on symbol number 3 (Figure 2) reveals that average achiever student could not fulfil second and third indicator of mathematical reasoning based on SOLO taxonomy on relational stage. This finding identified that average achiever student has a potential to pass multi-structural stage. Therefore, this finding could be a reference for further research. A research which able to develop students' mathematical reasoning ability which was from multi-structural to extend-abstract stage based on SOLO taxonomy.

4. Conclusion

Based on the finding above, it can be concluded that the highest stage of students' mathematical reasoning ability belongs to extended abstract in solving the statistics questions within mean material. The criteria are, the students are able: 1) determining the score order by seeing the patter and detect the order of one or more than one ration from some scores, 2) creating formula of generalization about the order of mean ratio between classes, to determine the ratio of amount of students in two different classes, 3) determining the relationship of amount of students between two different classes, 4) developing the generalization to determine the new mean when they are given the other mean of other class.

On the other hand, students' mathematical reasoning in the average ability stands in stage multi-structural in solving the statistics questions within mean material. It has criterion such the students are able to build connection between two ratios of some scores but cannot understand the relationship of concepts in amount of students from two different classes.

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