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The Statistical Reasoning Obstacles of Mathematics Pre-Service Teacher on Descriptive Statistics

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Abstract

Statistical reasoning is one of the objectives in statistical learning. But in reality students experience obstacles in learning process. Therefore, it is necessary to identify obstacles of statistical reasoning on descriptive statistical material and its causal factors. The identification process used qualitative research method with the research subjects are the students who are currently taking basic statistics course. Data collection was done by means of tests, interviews and study documents. The results of this study shows that pre-service mathematics teacher experience the obstacles of statistical reasoning in each descriptive statistical material. By acknowledging the obstacles students face in questions, it will be easier for teacher to design a learning process that will be carried out in class so that learning objectives can be achieved.

Keywords: *statistical reasoning, obstacle, descriptive statistical*

1. Introduction

Nowadays statistical data present in people's daily life matter such as the number of participants in debates or community actions, phenomena such as crime rates, population growth, disease spread, production numbers, educational attainment, employment trends, etc. [1, 2]. Given the large amount of statistical data available in everyday life, statistical learning is given at every level of education. Knowledge of statistics is needed to be able to interpret and understand and make good decisions for the statistical data. This is in line with the opinion of Moore [3] who defined statistics as a tool to solve problems that always occur in everyday life, at work, and in science. More specifically Sulivan [4] stated that statistics is the science that associated with gathering, organizing, summarizing and analyzing information to draw conclusions or answer questions.

Based on its function, statistics is divided into two types; they are descriptive statistics and inferential statistics. Descriptive statistics is statistics that only analyze and describe groups of data without making decisions for larger groups. Whereas, inferential statistics is statistics that analyze and describe groups of data to make valid decisions on larger data groups. Descriptive statistics include central tendency, variability and distribution [5]. Garfield and Ben-Zvi [6] stated that the main component in estimating data and graphical analysis and in understanding distribution is a central tendency. Central tendency consists of mean, median and mode. Variability is the same as dispersion and spread [5]. Variance consists of range, variance, standard deviation, and interquartile range. Distribution is considered as one of the main and important ideas in statistics [6]. Distribution is classified into theoretical distribution and empirical distribution [7]. Theoretical distribution shows the probability model including the normal distribution, whereas empirical distribution allows us to observe variations in data directly where central tendency, shape and distribution of data are common characteristics in distribution [6].

As for the objectives of statistical learning today emphasize understanding concepts and statistical reasoning rather than procedural understanding [5, 8 – 11]. By understanding concepts and qualified statistical reasoning, it will make students

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understand statistics well. This is in accordance with the purpose of learning statistics according to Rumsey [12] is students understand statistics well in order to obtain information from existing data, criticize and make decisions based on that information and aims to develop research skills [12]. At the university level statistics courses it has been assigned as a requirement for completing lectures in various fields of study [13].

Based on the purpose of learning statistics, statistical reasoning is one that needs to be mastered by students. Bennet [14] emphasized the importance of reasoning abilities possessed by modern society. Garfield and Gal [15] define statistical reasoning as a way of reasoning with statistical ideas and understanding statistical information. Ben-Zvi and Garfield [16] put more emphasis on how to use statistical information to think. Del Mas [17] suggested that statistical reasoning is the ability to explain why and how an outcome is produced and why and how to draw conclusions. Chan and Ismail [18] stated that there are four key constructs of statistical reasoning assessment based on the framework of Jones et al, namely: 1) describing data; 2) organizing and reducing data; 3) representing data; 4) analyzing and interpreting data. Based on the opinions above, it can be concluded that statistical reasoning is a logical thinking process that includes describing data, organizing and reducing data, representing data, analyzing data and interpreting data so that it can understand statistical ideas and interpret them based on the conclusions obtained from the given data.

Statistics is still considered a difficult subject that can hamper them in completing their studies [8]. The results of Chan, Ismail and Sumintono on their research [19] showed that students from elementary school to university level face difficulties in learning statistics. These difficulties occur due to the lack of knowledge of students' statistical concepts in the learning process. While the learning process takes place there are times when students experience obstacles in the reception process. These obstacles are caused by obstacles both from outside and from within that cause obstacles in achieving a goal. Bachelard and Piaget [20] stated that obstacles are not mistakes resulting from ignorance, uncertainty, opportunities as supported by empirical learning theory or behaviorist learning theory, but errors that are uncertain and unpredictable.

Cornu [21] classified these obstacles into four types: cognitive obstacles, genetic and psychological obstacles, didactic obstacles and epistemological obstacles. Meanwhile, Brousseau [20] stated that these obstacles can be caused by several factors, they are obstacle of ontogenetic origin (mental readiness of learning), obstacle of didactical origin (due to the education system) and obstacle of epistemological origin (knowledge of students who have context limited application). Moru [22] grouped learning obstacles as ontogenetic obstacles, cognitive obstacles, didactic obstacles and epistemology obstacles. Whereas Kumsa, Pettersson, and Andrews [23] stated that the factors which cause learning obstacles are epistemology (internal reasons due to mathematics itself), cognitive (due to the abstraction process and conceptualization involved) and didactic (due to learning). In this study, obstacles to ontology (student learning readiness), epistemology (the concept of statistics itself), cognitive (obstacles obtained by students in the learning process where information they had previously and internal processes of knowledge are only appropriate for certain problems), didactic obstacles (due to learning) and psychological obstacles (obstacles caused by psychological factors of students).

Several studies have revealed misconceptions and obstacles to statistics [14, 24 – 31]. Research conducted by Lee and Meletiou [25] and Saiman [29] focused more on the presentation of histogram data. Whereas, Bennet [14] and Paul and Hlanganipai [28] focused their research on probability. Researches that have been conducted mostly focus on one of the materials mentioned. This research will discuss the obstacles of statistical reasoning on descriptive statistical material and its causal factors. This is very important to study because by knowing the obstacles students face, the teacher will be easier to design a learning that will be implemented in class.

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2. Methodology

The study was conducted at STKIP Sebelas April Sumedang with the research subjects are the third semester students who are currently taking the basic statistics course. The method used in this study is a qualitative method. Data was collected by written tests, interviews and document studies. Written test results are the main data source to uncover students' obstacles on statistical reasoning. The written test is in the form of reasoning questions consisting of 5 questions in the form of a description, which includes data description (No. 1), data representation (No. 2a), organization and reduction (No. 2b), and analysis and interpretation (no. 3 and 4). The statistical reasoning test was carried out in one class with as many as 43 people. In conducting interviews, researchers do not conduct interviews on all students who take basic statistics course, only 6 students were interviewed. Students were selected for interviews based on the test results and activities during statistical learning. Document studies were conducted on learning and implementing tests. Data analysis was performed using the constant comparative method. In general, the data analysis process includes: data reduction, data categorization, synthesis, and ended with a working hypothesis.

3. Results and Discussion

Data is collected by conducting a written test. Written tests are used to identify statistical reasoning and the obstacles students experienced. Table 1 presents the results of students' statistical reasoning tests.

Table 1. The Test Result of Statistical Reasoning

Question	Problems Indicators	Answers (Number of People)		
		Correct	Wrong	Do Not Answer
1	Be aware of the completeness of the graphics (Title, axis and ordinate) that are displayed correctly and can explain and relate to actual data or graphics.	20	17	6
2a	Represent the same data in different forms	5	32	6
2b	Make a summary of the data using the data distribution correctly and can explain and relate it to actual data or graphics	2	25	16
3	Determine one measure of central tendency (median) based on data and known central tendency	10	24	9
4	Make comparisons between two different data correctly and can explain and relate to actual data	22	11	10

Based on Table 1, it can be seen that only in question no. 4 the number of students who answered correctly were more than 50%. In other questions students were not optimal in answering the questions. Following up on the test results, interviews and study documents were conducted. Interviews were conducted several times to obtain consistent answers. Document studies were carried out for the duration of the learning and test implementation. Based on the test results: interviews and document studies; statistical reasoning is grouped as follows.

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Table 2. Pre-service Mathematics Teachers' statistical reasoning on Descriptive Statistics

Questions	Reasoning Aspects	LPS					
		L0	L1	L2	L3	L4	L5
1	Data description			5	0	12	20
2a	Representation	6	7	0	10	15	5
2b	Organization and reduction	16	18	4	3	0	2
3	Analysis and interpretation	9	6	8	3	7	10
4	Analysis and interpretation	10	7	1	3	0	22

Descriptions:
LPS = Statistical Reasoning Level
L0 = No Statistical Reasoning
L1 = Idiosyncratic Level
L2 = Verbal Level
L3 = Transitional Level
L4 = Procedural Level
L5 = Integrated Process Level

The leveling or grouping is done by matching the existing conditions with the characteristics of the grouping conducted by Chan, Ismail and Sumintono [5]. But there are conditions where students only copy the questions or do not answer the questions given at all, and then L0 is used by Yusuf [32] because the characteristics are the same. Level of Statistical Reasoning (LPS) 0 is the condition when students do not write an answer but only copy the problem on the worksheet, meaning that the students do not have the ability of statistical reasoning [33]. In Figure 1, students' answers were presented in LPS 0 conditions.

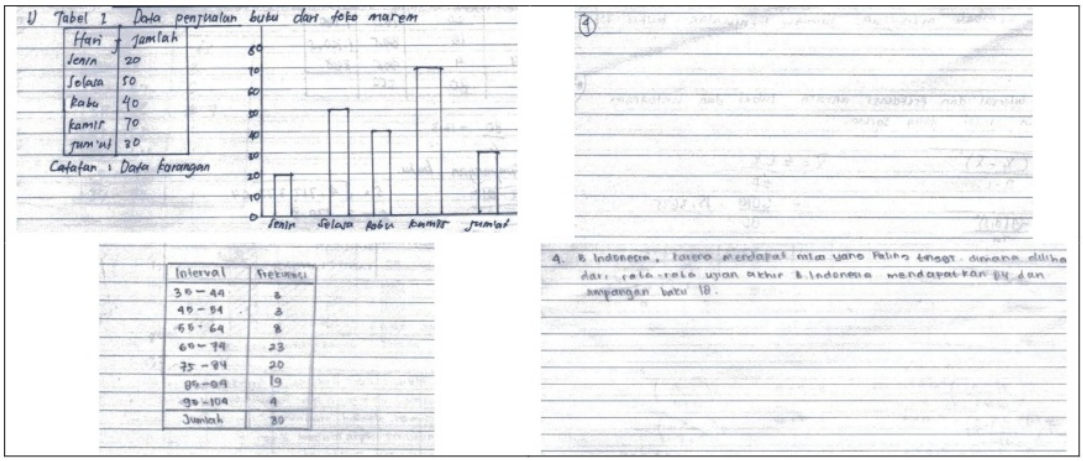

Figure 1. Student answers in LPS 0 conditions

The results above indicate that students experience obstacles in statistical learning so they do not understand the concepts and applications of these concepts properly. This is as stated by Jin, et al. [8] and Chiesi and Primi [34] that students do not know the concept, the relationship between concepts and how to apply these concepts in real life problems.

Problem 1 and 2a are questions of data presentation. However, problem number 1 is for single data presentation while number 2a is for group data presentation. The measured

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reasoning aspects are also different, in no.1 it is about data description while in no. 2 it is about the data representation. Both numbers are given because it will give effect in solving problems by creating a visual image. This is in line with the opinion of Owens and Clements [35] which stated that visual portrayal provides a very important role in the preparation and method of problem solving and provides a very strong influence in the way of constructing reasoning. As we know, problem solving in statistical reasoning requires a lot of visual images. For example, in the data normality, we can see a visual picture of normally distributed data if the data distribution is in a bell-shaped curve.

In question no.1 it was found that students experience cognitive obstacles, where usually the problem is presented with data description first then students are asked to present the data in the form of tables or diagrams. The given questions ask students to complete a bar graph whose data is initially presented in the table, and then students are asked to describe the data presented. Because the flow in working on the problem is different from the usual problem solving, students cannot answer the question correctly. Some of students only focus on how to describe the data presented in the table, but fail to complete the given bar graph. This is consistent with the evidence found by Gonzáles, Espinel, and Ainley [36] that pre-service mathematics teachers have higher competence in how to read graphs. Students claimed that they experienced anxiety so they forgot what they have learned and how to use it to solve the problems. Anxiety is one of the psychological factors that influence statistical reasoning. Onwuegbuzie [37] defined statistical anxiety as fear that occurs when a student is working on statistics in any form at any level. Yusuf, et al. [38] defined statistical anxiety as a feeling of worry, tension and fear when students study, work on and apply statistics. Students also acknowledged that they felt there was nothing that needed to be completed in the bar graph presented because they found the diagram in the textbook was not equipped by labels on the vertical and horizontal axis and the titles or labels of the bar charts. In addition, lecturer assumed students understood about the material of tables and bar charts so that they did not need to go thorough about this topic in learning process. Students are lack of learning readiness on this material; students tend to think of this material easily so they usually do not prepare it well. Based on the description above, in question number 1 students experienced cognitive, psychological, and didactic and ontology obstacles.

Problem no 2a is still about presenting data which are frequency distribution and histogram. Data was presented in the frequency distribution and histogram, where students were asked to explain whether the two presentations are from the same data. Students tend to only compare the height of the histogram with the frequency contained in the table; they do not pay attention to the value on the horizontal axis of the histogram. These obstacles are the same as the findings in the research of Lee and Meletiou [25] and Saiman [29]. Students assumed that histograms and bar charts are the same thing that is the presentation of a single data. This makes them unable to analyze the values contained on the horizontal axis the same or not with the interval in the frequency distribution table. The problems presented were different from what they are used to learn, data are usually presented then students just need to create a frequency distribution table and a histogram of the data. In working on problem number 2a, students felt confident and assumed this problem was an easy problem to solve. Material about histograms is considered easy material so that there are no notes about the histogram in the notes that are allowed to be taken during the exam. They only noted how to make a frequency distribution table. Based on these descriptions, in the material presentation of data in groups students experienced cognitive obstacles, epistemology and ontology.

Problem 2b is a matter of measurement of data distribution, the standard deviation. Students were asked to calculate the standard deviation then explain the meaning of the value of the standard deviation. Some students fail to interpret the standard deviation

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formula that causes errors in counting. In Figure 2. It can be seen the results of student misinterpreted the formula

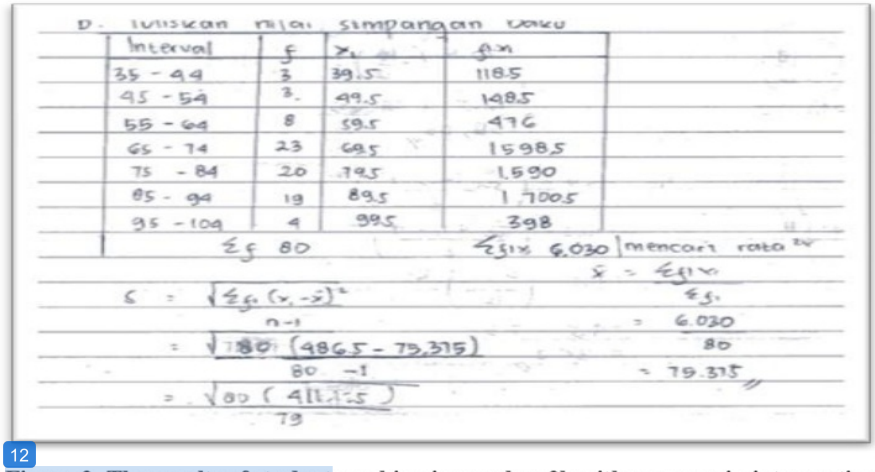

Figure 2. The results of student working in number 2b with an error in interpreting the formula

In this case, students only know the notation fi as frequency, Xi as the value of x, $\bar{x}$ as the average and n as the amount of data. Students do not understand the usefulness of the notation $\sum$ that lies before $f_i(x_i - \bar{x})^2$. If we pay attention to the answers of students above, students could understand the function of the $\sum$ notation used in calculating the average. The questions given are not problems with new types; the flow of working on the questions is the same as the flow of working on the problems that are usually given in learning. This indicates the existence of cognitive obstacles on students in interpreting the formula. There are also students who used the formula in calculating the standard deviation, where students used the standard deviation formula for single data not for group data. Incorrect use of this concept is related to the epistemology obstacles that students experienced. The results of students' works using the standard deviation formula for a single data can be seen in Figure 3.

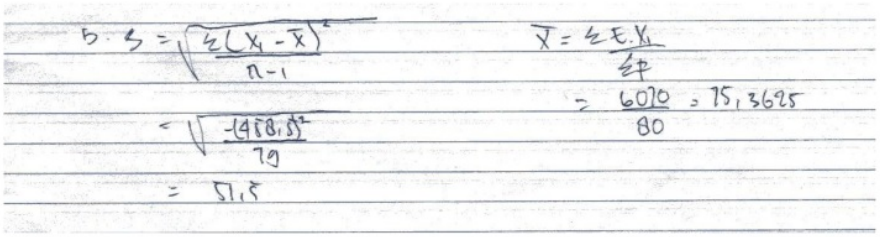

Figure 3. Students' works on problem no 2b using a single data formula

In addition to misinterpreting formulas and using incorrect formulas, there are also students who made mistakes in the calculation process. The numerical ability of students obviously will greatly affect the results of student reasoning. This is as stated by Wilson and MacGillivray [39]; Chiesi and Primi [34] who stated that the ability to think and statistical reasoning is clearly related to students' numerical abilities. Mistakes in using formulas and doing calculations should not occur, because when the test was conducted

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students were allowed to bring notes written on a sheet of A4 paper and were allowed to use a calculator as a counting tool. In the notes, students were allowed to record the concepts and formulas that have been taught, but they were not allowed to record examples of questions that have been given. The condition of students who felt the rush in doing the calculations and feeling insecure about what they have done that causes carelessness in doing calculations. Psychological obstacles are also experienced by students on standard deviation material. Students admitted, when asked to calculate the standard deviation they felt it was a difficult thing. In accordance with the findings of Mevarech [40] that students have difficulty in calculating variance. But contrary to the findings of Jacobbe and Carvalho [41] and Sánchez, da Silva, and Cautinho [42] which showed that prospective mathematics teachers have high competence in calculating measurements.

In addition to being weak in counting, students are also weak in interpreting results; there were only 2 students who could interpret the obtained results. The results of this study are in accordance with Leavy et al. [43] which stated that students have difficulty when learning to interpret graphs and statistical results. Teachers have emphasized the meaning of standard deviations related to central tendency. However, some books emphasized heterogeneity in the results of observations. It is also found is a book which only explain how to calculate variance but does not explain what the meaning of variance is. This is consistent with the findings of Lossen et al. [40] that many books emphasize variance as heterogeneity of observations rather than deviations from the size of central tendency. These findings indicate the existence of didactic obstacles associated with teaching materials.

Problem no. 3 is a matter of central tendency in which the average, median and mode concepts are used simultaneously in solving the given problem. Usually in learning only one concept is used in solving problems. The questions given in number 3 are as follows.

"Andi achieved Mathematics test score as follows, 6, 8, a, 6, b, c, 4. The average score of Andi's test is 5 and Andi most often gets a score of 4 in Mathematics test. Determine the median of Andi's test score! "

Only 10 students who could answer this question correctly. The solution to the problem above as follows.

$\bar{x} = \frac{\sum x}{n}$ (Average concept)

$$5 = \frac{(6+8+a+6+b+c+4)}{7} = \frac{(24+a+b+c)}{7}$$

$35 - 24 = (a + b + c)$

High possibility that a = b = 4, because 4 need 2 more points to make it into mode in the data, and assuming that a = b = 4, hence

$11 = 4 + 4 + c$
$11 = 8 + c$
$c = 3$

Therefore, the sorted data becomes: 3, 4, 4, 4, 6, 6, and 8
Median $= \frac{(n+1)}{2} = \frac{7+1}{2} = 4$ (the 4th data) (median concept)
The fourth data of the sorted data is 4.
So the middle value of Andi test score is 4.

As many as 33 students cannot solve the problems as above with various obstacles. There are students who do not know what concepts to use in solving these problems. Yet in learning students are very skilled in calculating the average value, median and mode for

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a single data. The information from questions that are different from the concept of central tendency that is in their minds made them fails to process new information. This makes them unable to determine the step that must be used in solving problems in the problem and the relationship between the concept of average, median and mode. It is assumed that cognitive obstacles that cause this to happen, where students failed to acquire knowledge because the process of assimilation and accommodation was blocked. This is as stated by Nursit [44] that cognitive obstacles will hinder the process of assimilation and accommodation so that students experience obstacles in acquiring knowledge. The process of assimilation itself is a process in which children evaluate and try to understand new information based on existing knowledge, while accommodation is a process in which children expand and modify their mental representations of the world based on new experiences [45].

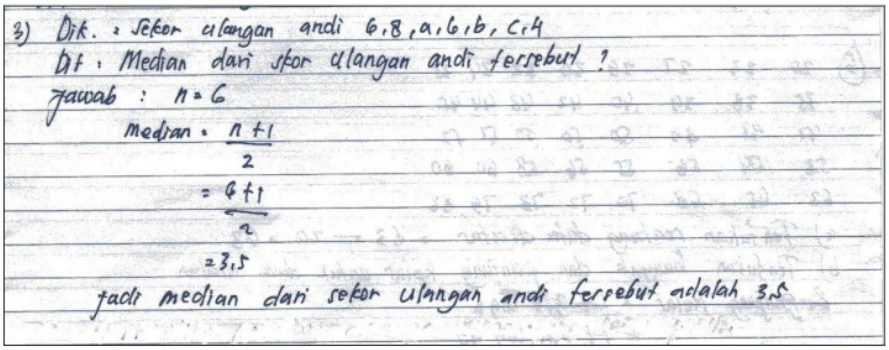

Figure 4. Students' answer on problem number 3 with epistemological obstacles

In number 3 also some students determine the median value without sorting the data. They assumed that the median is the middle value of the data. In addition to determining the median without sorting the data, students also misinterpret the location of the median and the median value. This case is calles the epistemology obstacle. In accordance with the opinion of Jannah, et al. [46] that the misunderstanding to define and to perform formal definition is calles the epistemology obstacle.

Students assumed that determining central tendency from a single data is an easy material so that they did not practice much and get prepared for this material. They only paid attention to the examples of questions that have been given in learning. Of course this results in ontology obstacles where they were lack of learning readiness for this material. This lack of readiness causes feelings of doubt, anxiety and panic when resolving the problems. These feelings cause errors that should not occur such as mistakes in making calculations. Mistakes in doing this calculation should not occur because not only they use calculating tool, the data in the problem is also not in a large number. Students admitted that there was sufficient explanation of central tendency in learning. However, the lack of practices regarding the use of the central tendency concept simultaneously makes students difficult in solving the problem. There are not many teaching materials that provide examples with the similar problems such as in the questions above. The explanation above reveals cognitive obstacles, epistemology, ontology, psychology and also didactic obstacles experienced by students in the matter of central tendency.

Problem 4 is a matter of standard scores (z), which is used to solve the concept of average size and standard deviation simultaneously. In this problem, many students could answer the question correctly. This type of question has been given to students in learning. All students should be able to complete it, as stated by Batanero, Godino,

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Vallecillos, Green and Holmes [40] that most students have no difficulty in understanding concepts and calculating standard scores (z). But there are a few students who experience obstacles. There is an answer from students who directly solve the problem by comparing the scores of the two data without regarding the average and standard deviation, even though the data is different. They remember previous knowledge in their minds that the greater value is the better, though we cannot compare a situation in different conditions. In order to be able to compare the two different conditions we have to make these conditions into the same term by changing the existing score to a standard score (z). There are also students who have successfu 26 conducted the analysis correctly but were unable to explain the results of the analysis. Students failed to make the relationship between the results and the existing problems. The inability of students to create a flow of completion, lack of prerequisite knowledge, wrong intuition and weak understanding of the relationship indicate that cognitive obstacles are experienced by students in solving this problem. Feeling anxious that they would not be able to finish solving the problem made them rush in doing the counting process even though they knew the workflow but this anxiety was still experienced by students. Knowing the workflow shows that students have prepared this material. On standard score problems (z value) students experienced cognitive and psychological obstacles

4. Conclusion

Obstacles experienced by pre-service mathematics teacher in this 1 statistical reasoning occur in every descriptive statistical material. As for the obstacles that occur in the material presentation of a single data with the reasoning aspect of data description: cognitive obstacles (students cannot solve the problems given because the workflow is different from the problems that are usually given in learning), psychological obstacles (students feel anxious when working on the test reasoning), ontology obstacles (students do not study the material because they consider the material easy), and didactic obstacles (lack of emphasis on attributes in tables/diagrams and there are still teaching materials that present tables/diagrams without complete labels). Obstacles experienced by students in working on problems about group data presentation with the aspect of reasoning representations of data are cognitive obstacles (the problems presented in the test have different solving steps with the problems commonly worked in learning and students fail to make the relationship between the horizontal axis (x) on the histogram with intervals in the distribution table frequency), epistemology obstacles (students assume the histogram is the same as a bar chart), and ontology obstacles (students only focus on preparing the frequency distribution material so that they do not prepare for the histogram material). In the question with data distribution material on indicators of organizational reasoning and reduction there are cognitive obstacles (students cannot interpret the standard deviation formula and students do not know the relationship between standard deviations with central tendency), epistemology obstacles (students use standard deviation formula of single data to calculate standard deviation of group data), and didactic constraints (teaching materials that only explain how to calculate the standard deviation but do not explain their application and their relation to central tendency). Obstacles experienced by students in the matter of central tendency with aspects of reasoning analysis and interpretation are cognitive habit (students cannot determine the step that must be used in solving problems in given questions and students do not know the relationship between concepts of average, median and mode), epistemology obstacles (students use location of the median formula to determine the median value and students do not sort the data in advance in determining median, ontology obstacles (students do not have much practice and only learn the material that has been taught), psychological obstacles (feelings of doubt, anxiety and panic in determining completion) and didactic obstacles (lack of practice questions with the use of average, median and mode simultaneously and both in teaching and in teaching materials). In the matter with standard score material on the

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reasoning aspects of analysis and interpretation, students experienced cognitive obstacles (wrong intuition in determining the best conditio[23], unable to determine the flow of completion by utilizing the relationship between mean and standard deviation, lack of knowledge about the standard score, and cannot interpreting the results of calculations with existing problems) and psychological obstacles (students are worried not being able to solve the problem).

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