Students' Ability of Statistical Reasoning in Descriptive Statistics Problem Solving

Nila Kesumawati
Universitas PGRI Palembang, Jl.Jend. A. Yani, Lrg. Gotong Royong 9/10 Ulu, Palembang, Indonesia
Department of Mathematics Education, Universitas PGRI Palembang, Indonesia

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Abstract: The problem of this research was some students unable to interpret the results of calculations in solving the problem of descriptive statistics associated with the statistical reasoning. Students were able to solve the problem procedurally only without understanding the meaning of the calculated results. Students knew the concept, but they could not identify the use of the concept. This descriptive quantitative and qualitative research aimed at describing the students' statistical reasoning ability in solving the problem of descriptive statistics. The subjects of this research were 134 students of mathematics education and sports education, University of PGRI Palembang. They were chosen using purposive sampling because they enrolled in Basic Statistics Course. Reasoning test and interview was used to collect the data. The results stated that students' statistical reasoning ability is in the multi-structural level category. This can be known from the ability of statistical reasoning based on the measurement of Reading and Reid. In Prestructural Level there were 2 students who have no clear conceptual foundation; and in the Unistructural Level there were 25 students focusing on one concept of statistics; at multi-structural level there were 104 students who focus on more than one statistical concept; and at Relational Level there were 3 students who develop relationships with various other statistics concept.

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1 INTRODUCTION

Basic statistics is one of the important courses in curriculum 2016 which based on KKNI, so the students are expected to understand and implement it. Statistics as knowledge provides a means to solve the phenomenon or problems of life, in the working environment, and in the science itself, as well as a tool for evaluation of what has happened in determining future policy (Moore, 1997; Kadir, 2015; Kesumawati, et.al. 2017). According to Sundayana (2012), basic statistics course has four aspects to be achieved, such as: (1) to provide theoretical knowledge to the students; (2) to provide practical skills in the form of statistical calculations; (3) to provide an overview and experience of how to solve problems with daily life related to problems; and (4) to train students how to communicate the results of the study, both in written and oral form.

The ability of students to communicate the results of his studies by explaining or answering questions about interpreting the results of calculations is part of writing in communicating understanding. NCTM (2000) stated that writing is the way of communicating mathematics and reinforcing students' thinking, as this may affect their thinking about ideas and concepts that writing as the most important element in learning mathematics. In addition, writing also can support mathematical reasoning with problem-solving and as a tool to internalize the characteristics of effective communication. In line with, Bosse and Faulconer (2008) stated outlined procedures that can be employed in mathematics assessment to create experiences that promote reading and writing as tools for expressing mathematics understanding.

The researcher often sees students have difficulty in interpreting the results that have been done. Based on Lanani's research (2015), some of the weaknesses for students in the course of statistics during this time are these materials: classification of statistical data types, representation of statistical data, measurement of statistical data, sample as a representation of the population, and hypothesis testing.

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Associated with the weakness for students in statistics during this time, it is often encountered that many students have not been able to interpret the results for problem-solving of descriptive statistics. Besides the weakness for statistical ability is also experienced by the teacher. This is evidenced based on the results of research that has been done by Martadiputra (2010). It was found that statistical reasoning ability of mathematics teachers, in both junior and high school, on the material statistics descriptive median material, population, and sample are categorized very less; material representation data and central tendency are categorized enough. Overall, the average statistical reasoning ability of them was in the medium category. In 2012, research of Martadiputra was continued and still about the statistical reasoning ability of undergraduate student majoring in mathematics education at a State University in Bandung. The results show that students' statistical reasoning ability is in a low category. Other evidence is from community service activity conducted by lecturer majoring in mathematics education UPI in Kabupaten Subang (Avip, 2010). It was found that the mean statistical reasoning ability of teachers in the junior high school and the senior high school reached 46% in the medium category.

Statistical reasoning is a reasoning activity on statistical materials which is the developed statistical ideas form skills in using statistical concepts (Lanani, 2015; Gal and Garfield, 1997; Garfield and Chance, 2000). The important understanding of statistical concepts in statistical ideas, such as central tendency, deviation, various data presentation, and correlation is part of the statistical reasoning.

All this time, statistics is considered only as a science for the solution to problems that are mechanistic. However, it has a lot of usefulness in everyday life related to principles if it is studied further. This statement is supported by Dasari (2009: 40), that statistics are still considered only as a series of the thinking process. Teachers and students emphasize more on the particular rather than the principle, the emphasis on mechanistic rather than the main methodology, and the emphasis on a special formula rather than a common one.

Specifically, the use of statistics is to describe and predict based on phenomena as the collection of results from the study. The ability of statistical reasoning is needed to interpret and represent data onto determining the correct decision on the data. According to Dasari (2009), the ability of statistical reasoning is the ability to make conclusions and provide explanations based on data orientation with respect to structured procedures, unstructured procedures, and statistical concepts, and interpret the process and statistical result.

Furthermore, Del Mas (2002) interprets statistical reasoning as the ability to explain why and how a result is processed and why and how to draw conclusions. To find out how far the students' statistical reasoning abilities, it is surely needed measurement tools. The required measuring instruments are the indicator of statistical reasoning ability. According to La Nani (2014), indicators of statistical reasoning ability are that students capable of: (1) summarizing and explaining based on data orientation; (2) understanding and interpreting process and statistical results.

The aim of this research is to assess students' reasoning statistical ability on central tendency, deviation and data representation through essay examinations particular, the question posed in this research is how the student's level of statistical reasoning in basic statistics courses seen from the way students answer/explain: (1) Prestructural; (2) Unistructural; (3) Multistructural; and (4) Relational.

This research attempts to be different, yet complementary, the emphasis on describes students' statistical reasoning ability in descriptive statistics problem solving based on the levels developed by Reading and Reid (2006), i.e. pre-structural, unistructural, multi-structural, and relational. It is a little information about how students have studied basic statistics courses to interpret the results obtained, and such research is rare in colleges in South Sumatera. This research contributed to (1) the basis of knowledge for students, and (2) as the basis for students in the course.

2 RESEARCH METHOD

This research used descriptive quantitative. The instrument of this research was essay test that had been validated by expert and had been declared valid. The test made based on mathematical statistical reasoning which consist of 5 questions. This research was conducted at PGRI University of Palembang included 134 students of academic year 2017/2018. It covers undergraduate students of the second semester in mathematics education program and the third semester in sports education program. The reasons for choosing the students are that: (1) the students are following the basic statistics course; (2) the students are more easily managed by the researcher to follow the planned research procedure.

Data was collected through essay test and interview. In collecting the data, researcher giving an essay test material consists of central tendency, data deviation, and data representation at the middle of semester. Students explain or interpret the results of the research in descriptive statistics, which are necessary to determine the level of students' statistical reasoning. The development of essay tests based on reasoning statistical ability indicators has been validated to determine student responses to research instruments. Interview was conducted to find out more student's reasoning of their answer sheets.

The level of statistical reasoning with this research is guided by Reading and Reid (2016) that has four phases and arranged hierarchically in Table 1.

Table 1. Phase of Statistical Reasoning

Reasoning Level	Descriptions of Statistical Reasoning
Prestructural	No obvious concept based.
Unistructural	Only focuses on one statistics concept.
Multistructural	Focusing on more than one statistics concept.
Relational	Developing connection to another statistics connection.

Furthermore, after analyzing the results of student answers, the aspects used and the level of statistical reasoning is adapted from Yusuf's which has been modified (2017), can be seen in Table 2.

Table 2. Phase of Statistical Reasoning for Statistic Data Measuring

Phase 1	Phase 2	Phase 3	Phase 4
Prestructural $0 \leq$ score ≤ 20	Unistructural $20 \leq$ score ≤ 50	Multistructural $50 \leq$ score ≤ 90	Relational $90 \leq$ score ≤ 100

3 RESULT AND DISCUSSION

From the results of examination in quantitative and qualitative, completion of the students' essay resulted four identification level. These four levels are adopted from the description of Reading and Reid (2006) modified SOLO taxonomic. The description of each level is as follows: (1) the student does not have obvious conceptual foundation. It means that they are only able to determine the data of the problem but cannot continue the solution onto the problem. It categorized at prestructural level; (2) the students are only focusing on one statistical concept. It means that they can use only one information such as the problem of determining standard deviation value and variance and not yet know the relationship between them as well as the relationship between mean, median and mode of data. It is categorized at level Unistructural; (3) the students focus on more than one concept of statistics. It means that they can use some information but do not connect. It is categorized multistructural level; and (4) the students can develop relation to other statistical concepts. It means that they have completed understanding of the process, the relation of rules and the use of statistics, and students can conclude in their own words. It is categorized relational level.

Results of students' overall statistical reasoning appraisal (average = 57,2 and SD = 12,6) included in the multistructural level category. This result is in line with other findings about the average ability of statistical reasoning ability (Dasari 2009; Martadiputra, 2012; Avip, 2010). The following are four main findings of the study based on Reading and Reid (2006).

1. Statistical reasoning ability at prestructural level is only reached by 2 students (1.5% of all students) who have no obvious conceptual base. At this level, students cannot start an essay because they do not try to focus on the problem. They are distracted by irrelevant things. Students still think the more dominant concrete-symbolic way so that students cannot answer the problem to choose and give reason. From 134 students that became the subject of the research, there are 2 students at the Prestructural level.
2. Statistical reasoning ability at unistructural levels is reached by 25 students (18.7% of all students) focusing only on one concept of statistics. At this level, the student can focus on the problem, generally only focus on one aspect. They can answer issues related to central tendency and dispersion tendency of data given. In addition, they can solve the Pearson slope problem and the coefficient of tangles. They are also able to show that a curve is normal, oblique to left, or right oblique. They have a higher tendency to support their answers by completing the ordered data. From 134 students who became the subject of research, only 25 students are at the level of Unistructural. Figure 1 is an example of the

results of student's work that can determine the results of calculations and can determine that the data is oblique to the left. The student also understands that the more pointed a curve then the smaller standard deviation so that the data homogen.

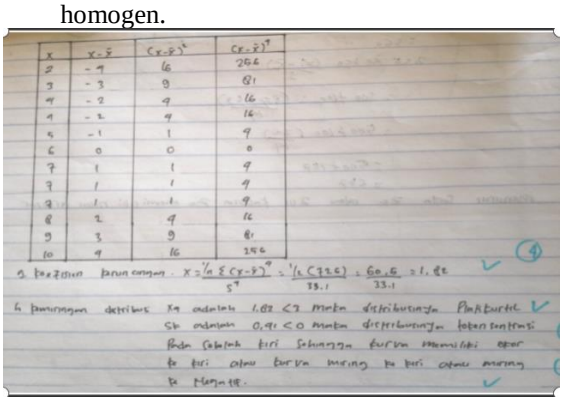

Figure 1. Student's Answers Material Deviation

3. Statistical reasoning abilities at multistructural level are reached by 104 students (77.6% of all students) focusing on more than one statistics concept. At this level, students display the ability to think quantitatively and know more than one aspect of data exploration. Generally, there is a concrete-symbolic way of thinking and has a concept that is more than one relevant aspect. They can interpret histogram and frequency polygon images into the table frequency distribution. In the histogram and the known frequency polygon, only middle scores and the frequency is showed, but 30 students cannot determine the lower and upper limits for each interval. At this level, students can change the value of z to standard numbers in order to determine which candidates should be accepted and give reasons. From 134 students that became the subject of research, there are 104 students are at the Multistructural level. Figure 2 is an example of a student's answer in interpreting the results after the calculation.

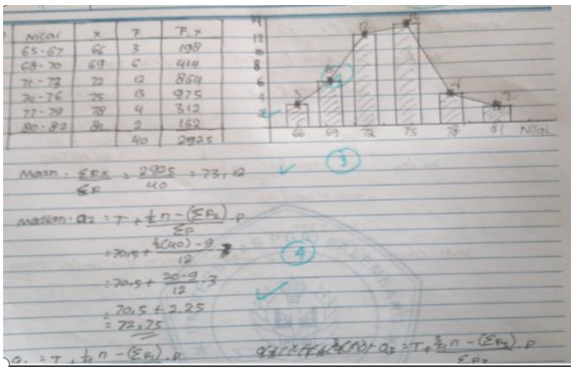

Figure 2. Student's Answer on Material of Data Presentation

Student was interviewed about their reasoning to solve the problem. The students observed the bar chart from the problem then remember how to create a frequency distribution table that the interval should be the same. After creating a frequency distribution table, they analyze data from the table to determine the central tendency. It means that the student knows more than one concept, i.e. presenting data from bar chart to frequency distribution table, determine central tendency of it. Another example of student answers can be seen in figure 3. It can be showed that the result is wrong in determining the length of the interval. Only first interval class has right length of interval. Otherwise, the next interval class is wrong. It is because carelessness so that there is an error in making the table distribution of frequency.

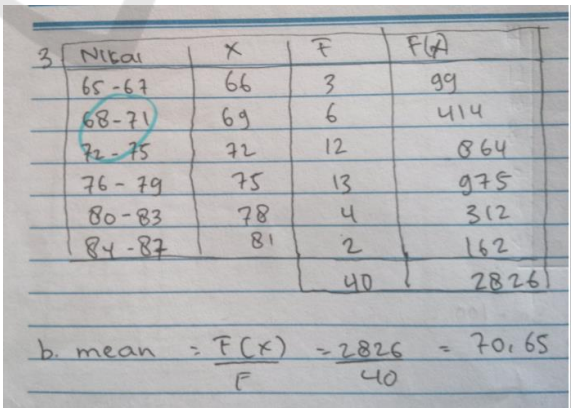

Figure 3. Student's Inaccuracy on Material Creating Table Frequency Distribution

4. Relational level of statistical reasoning ability is reached by 3 students (2.2% of all students) who can develop relation with various other

statistical concepts. At this level, students display the ability to think analytically and quantitatively about the data and be able to explain various perceptive based on the data obtained. From 134 students who became the subject of research, there are 3 students who are at the level of Relational. Figure 4 is an example of student answers.

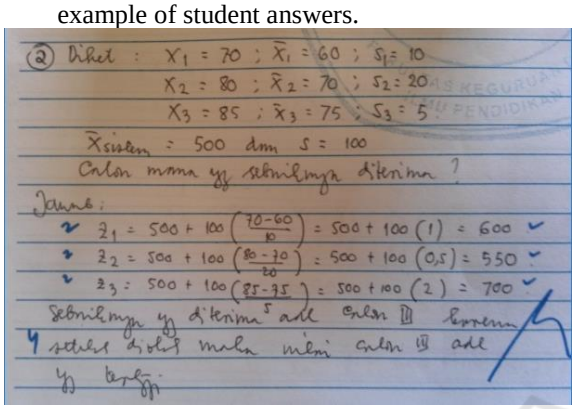

Figure 4. Student's answer to the material of z-score

Student was interviewed about their reasoning to conclude who is the best candidate to be accepted. The student using z-score to determine the best candidate because there were given value of x, mean, and deviation standard of each candidate. It means that the student can relate various statistical concepts.

In this research there are two important limitations. First, the source of assessment provided for the analysis was an essay and the second was the three basic statistical topics i.e. central tendency, data deviation, and data presentation. This research provides rich analysis through response comparisons showing various levels of students' statistical reasoning. It then offers insight into how the students' statistical reasoning can influence the lecture strategy in order to interpret the data.

The level of statistical reasoning can be as a guide in identifying the weaknesses and strengths of students in statistical reasoning (Joseph, 2017). According to Rumsey (2002) the purpose of learning statistics is that students understand statistics well in order to make decisions and can develop research skills. In addition, Lanani (2015) argues that statistical reasoning plays a role in shaping students' skills using concepts, rules and statistical processes. Olani, et al (2011) states that the ability of statistical reasoning refers to the ability to understand and integrate statistical and ideas to interpret data and make decisions based on statistical concepts.

Lovett (2001) found that to understand and improve students' statistical reasoning, needs integrating three approaches, literature study approach (theoretical), empirical studies, and classroom-based research. Chan and Ismail (2014) stated that there are five statistical reasoning tasks in the assessment instrument which have been created based on the initial statistical reasoning framework, each item is associated with the sub-processes of four key constructs, i.e. describing data, organizing and reducing data, representing data, and analyzing and interpreting data. The dynamic spreadsheet of GeoGebra software is used as a technological tool in solving tasks. This statistical reasoning assessment instrument can be utilized by instructors and researchers for further investigation in future studies.

Agus et. al. (2013) concluded to develop a measurement instrument to assess undergraduate students' statistical reasoning on uncertainty and on association, in relation to methods of proof presentation. By the construction of paired items in two forms, we could compare the reasoning applied to problem resolution, regarding the specific problem structure. Furthermore, Pimenta (2006) found new technologies involve a reformulation of contents and methodology used for teaching statistics. Developing students' statistical reasoning becomes an important task for teachers of applied statistics. This is particularly true in the field of health sciences. In this work the statistical reasoning ability acquired by health sciences students was evaluated in the context of their final undergraduate project.

4 CONCLUSIONS

Based on the research result, the conclusion of this research is that the students' statistical reasoning ability in problem solving of descriptive statistics is in the multistructural level category. In detail, the statistical reasoning abilities obtained based on Reading and Reid measurements, i.e. in Prestructural level categories there are 2 students has no clear conceptual foundation; in unistructural level category, there are 25 students only focus on one concept of statistics; in the multistructural level category, there are 104 students focusing on more than one concept of statistics; and in the relational level category, there are 3 students developed in connection with various other statistical concepts.

According to the limitation of this research, for further researcher who will conduct similar research,

it is suggested that: (1) the instrument is not only using essay but also completed with interview and observation; (2) the topic should be extended, because the more topics is used the more it will be known the whole ability of students' statistical reasoning.

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