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Statistic problem solving based on cognitive style: statistically thinking

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Abstract. Statistical thinking is fundamental for humans' live, particularly to help them make careful and thorough decision. Besides, it makes them change the ways they apply from traditional to scientifically rational manner. Therefore, teaching statistics since elementary school is necessary. Based on the curriculum of mathematics in Indonesia, statistics is first introduced in the 6th grade of elementary school. However, some studies suggested that the lower graders were found successful in solving statistical problems. This study aimed to investigate the statistical thinking of an elementary female student in terms of her cognitive style. A qualitative approach was selected to describe students' statistical thinking in detail. The result found that a female student with field-independent cognitive style solved a statistical problem by several procedures, including: identifying data, describing and displaying data, organizing and reducing data, representing data, analyzing data, and making conclusion. Representation by a field-independent female student allowed her to make a comprehensively contextual response between the data on table and on bar chart.

1. Introduction

Statistical thinking is a capability to see and understand a statistical process as a whole, and apply it on real problems by providing criticisms, evaluations, and then make a generalization in regard to: 1) data description, 2) data organization, 3) data presentation, 4) data analysis and interpretation. [1][2] 3) argued, "*Statistical thinking involves an understanding of the nature of sampling and how we make inferences from sample population*". [3], in their study, argued that statistical thinking represented process engaged in a practice of data-oriented statistical investigation to take conclusion. Thus, it infers that if one has statistical thinking, he/she is able to see various data and information to be analyzed and then find any possible opportunities and threats that may happen in the next future.

[4] Developed a framework of statistical thinking toward elementary graders (from 1st grade to 5th grade) to show a statistical thinking in terms of understanding and describing various data display. A theoretical review Jones used was four constructs of statistical thinking derived from [5] with several modification including: illustrating, organizing, reducing, analyzing and interpreting the data. The construction of a process of thinking is known as DORA which is (1) [D] for *Describing data display*, one is able to read the data and show a complete consciousness for both data and graphic; (2) [O] for *Organizing and Reducing Data*, one is able to classify the data into classes with various ways and able to describe the nature of those various grouping; (3) [R] for *Representing Data*, one is able to construct a different display; (4) [A] for *Analyzing and Interpreting Data*, one is able to provide comprehensively contextual responses of the data display. Thus, statistical thinking intended in



this present study refers to elementary students' mental activities that show their statistical capabilities including: describing, organizing, reducing, representing, analyzing, and interpreting data. Furthermore [6], it was argued that the development of elementary students' cognitive was on concrete operation stage (7-11 years old). In this stage, students have more organized sequence of thinking, less egoistic nature, and limited consideration on things and abstract/imaginative approach.

On the process of problem solving, students are engaged in a process of thinking. It is seen when they are trying to understand the problems, they need to see and identify what facts or information are provided, what it is asked for evidence. In addition, it aims to see how they explore particular information of the given problems, either in the form of pictures or mathematical data, and see that the students are able to classify all those information. Statistical problems provided here relates to single-data centralization, in case to see how the students do the data display and analysis, and make conclusion from it. They are asked to make a single data identified from some parts of another data and to display it in diagram/chart (picture), respectively. The answer of each student is varied, since it is an open problem. In order to solve the problem, the students may use either a concept of single-data centralization or several problem-solving strategies such as trial-and-error, calculating any possibilities, starting from the reverse side, or trying to apply the solution on a simple problem as [6] has proposed.

Several factors may influence the students on their ways to solve problems. Those include their cognitive capability, the velocity of processing information, and the cognitive style and roles that different gender play on solving the problem [7]. Thus, it shows that the different gender –male and female students- influences them in solving mathematical problems. In addition, the different gender and cognitive style bring effect on students' learning outcomes as well, hence, it is possible for them to have different process of statistical thinking between male and female students with cognitive style *FI-FD* in solving statistical problems. This present study, however, aims to describe the process of statistical thinking of female students on elementary grade in terms of their cognitive style in solving statistical problems.

2. Method

2.1 Subject

This research is descriptive qualitative and it aims to image and describe the statistical students' thinking of the fourth grade in elementary school in solving statistical problem with *Field Independent* (FI) cognitive style. The research subject is female students of *field independent* in fourth grade of elementary school SD Negeri Jombatan 3 Jombang East Java, Indonesia. The female subjects chosen according to [8] stated that females were better than boys in presenting the answers both in verbal and written way. While in determining the subjects with *Field Independent* (FI) cognitive style, it is used *Group Embedded Figure Test* (GEFT) and mathematics target. Data was taken from the statistical problem given and unstructured interview consisted of questions to dig out the statistical thinking aspects.

2.2 Instrument

The instruments of this study include: 1) GEFT (Group Embedded Figures Test) adopted from [9] and it is useful to classify the students' cognitive styles including field independent and field dependent; 2) test sheet containing statistical problems. This study observes the process of statistical thinking through observation and in-depth interview, respectively. The results of both observation and interview are then analyzed and explained thoroughly. The test of statistical-problem solving is presented on figure 1 as follows.

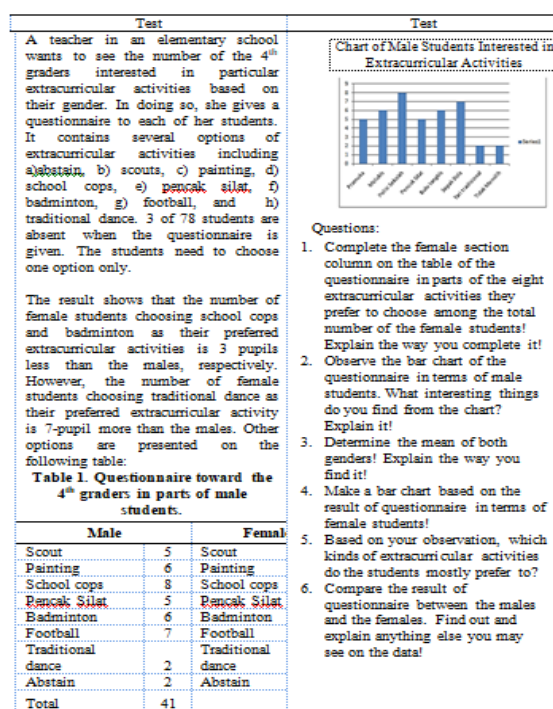


Figure 1. Test of Statistical-Problem Solving

2.3 Procedure

This research used qualitative approach. It aims to image and describe the statistical thinking process for the female fourth grade students at the fourth grade with *Field Independent* (FI) cognitive style in solving statistical problem. According to [10] researchers adopts the explorative approach to analyze the data Creswell, J.W. By using statistical problem, the subjects were interviewed to describe the statistical thinking aspects in solving statistical problem. Statistical problem refers to the contextual statistical problem which applies more than one different method to solve it. Time triangulation is used to get credible and suitable data for the facts. The data is analyzed, categorized, reduced, and interpreted to make a conclusion.

2.4 Result

2.4.1 Identifying Data

The students identified several elements such as information related to the number of the 4th graders feeling interested in extracurricular activities, the kinds of gender, and the relevant data in terms of male students. The subject tried to explore all information that seemed relevant, whether in the form of pictures or mathematical data. In addition, the subject showed the consciousness of the data.

2.4.2 Describing and Displaying Data

The subject looked into the task of statistical problem-solving based on their previous experience. The identified data was used to present a distinctive data display. The subject argued that the data displayed in the form of table seems easier to observe. On bar chart, the subject presented the data of students feeling interested in extracurricular activities in part of male students, however, she found herself difficult to determine the total number of male students interested to participate in extracurricular activities. The following interview described this matter.

2.4.3 Organizing and Reducing Data

The subject conducted data reduction in order to obtain a new measure which is helpful to describe another data. This was apparent when she organized a counting operation to determine the number of female students interested in extracurricular activities in the form of table. Based on the previous data in terms of the number of male students interested in extracurricular activities, the subject organized the data by collecting relevant

information and applying trial-and-error method. The structure of data organization and reduction was seen on the subject's work, as presented in Figure 2 and Figure 3.

Siswa perempuan, banyak? Pilih! Pilih salah satu Bulu tangkis, basket?
 Laki-laki: 5 orang dari banyaknya pilih laki-laki?
 Perempuan: 3 orang
 Bulu tangkis: 6 orang
 Perempuan: 3 orang
 Pilih: 8 - 5 = 3 orang
 Bulutangkis: 6 - 3 = 3 orang
 Sedangkan pada tari tradisional lebih banyak 7 orang dari pilih laki-laki?
 Laki-laki: 2 orang
 Perempuan: 2 orang
 Tari tradisional: 2 + 7 = 9 orang
 Informasi tentang kegiatan Ekstrakurikuler yang diikuti Siswa Kelas IV Laki-laki dan perempuan disekolah dasar.

Figure 2. Subject SPFI organized and reduced data

Siswa berjumlah 78 orang
 Siswa yang tidak hadir 3 orang
 Siswa laki-laki: 41 orang
 Siswa Perempuan: $78 - 41 = 37$ orang

Siswa Perempuan	
Pramuka	3
Melukis	8
Polisi Sekolah	5
Pancakilat	5
Bulutangkis	3
Sepak bola	3
Tari tradisional	9
	36

Tidak memilih 1 orang $36 + 1 = 37$ orang

Figure 3. Subject SPFI organized and reduced data

Figure (2) shows the process of a simple counting operation based on the previously informed information. The subject determined the quantity of each kind of extracurricular activities based on the predetermined criteria of quantity. The number of female students choosing school cops and badminton as their preferred extracurricular activities was 3 pupils less than the male, respectively. Similarly, Figure (3) shows the subject's activity to solve the problem by trying to take particular quantities that seems relevant with the given information into the table. The interview talking about this notion with the subject is as follows.

P Explain the quantities you see on the table!

SPFI The total number of students in the 4th grade of elementary school studied here is 78 students.

The number of student deciding abstain is 3 students who 2 of them are male.

The number of female students choosing badminton and school cops as their preferred extracurricular activities is 3 pupils less than the male, respectively.

This indicates that if the number of male students choosing badminton is 6 students, the number of female students choosing badminton as their preferred extracurricular activity is 3 students; and if the number of male students choosing

school cops is 8 students, the number of female students choosing school cops as their preferred extracurricular activity is found 5 students. Other options will be filled without any particular conditions

The subject determined the size of centralization by simply considering the options with extreme quantities, including the most preferred one, the least preferred one, and the frequent quantity. She looked into the data in both table and bar chart. She determined the mean of the data by estimating the quantity that seems closest valid, as she was unable to calculate it mathematically. The subject claimed that she did not recognize the terms on the size of data centralization such as mean, media, and modus yet. However, when she was asked about the average number of male students interested in extracurricular activities, she said that it was 5, since either '5' was frequently apparent or there was a kind of extracurricular activity with similar number of students interested in. She illustrated it visually by drawing a straight line that cut the bars and then shading each of the bars, whether each of which went over or under the line. The size of the straight line cutting those bars was derived from the same quantity on the number of students interested in the extracurricular activities. The following interview shows the size of data centralization in simple way

P So, now.. How is the mean of male students interested in extracurricular activities?

SPFI About 5 or 6

P How come?

SPFI I saw it from the similar number of the students interested in extracurricular activities.

P Why didn't you take 2 as the result? There are also 2 extracurricular activities with the same number of students interested in, right?

SPFI I think it is too far from other quantities. However, (for this matter) I prefer looking at the bar chart.

Too far? How could you say that?

If the mean is 2 and (on the other hand) 8 is there. The order will become like this: 2, 2, 5, 5, 6, 6, 7, 8. So, the mean is probably 5 since the difference toward the least quantity equals to the difference toward the biggest quantity.

5-2=8-5

The subject listed number based on the information informed on the table from the least quantity up to the biggest one. In addition, she made a presumption from the same quantity that seemed repeatedly apparent. She chose either 5 or 6 and argues that the difference between the least and the biggest quantity was equal.

2.4.4.Representing Data

In regard to data presentation, the subject concentrated on the relevant information previously given. She represented the number of female students feeling interested in extracurricular activities on the table, and made a bar chart to present the other data. She drew two lines –horizontal and vertical- which cut each other in one point. Each of those lines was attributed with the same scale of distance marked with some dots and named for each

point. She wrote some numbers from 1 to 9 on the vertical line and name horizontal line with the kinds of extracurricular activities.

2.4.5 Analyzing and Interpreting Data

The subject analyzed and interpreted the data by comparing between the general data and the data display, between the data set showing the number of students interested in extracurricular activities in part of female and male students. She was more likely to compare the data by identifying the options with extreme quantities, whether in parts of male or female students.

The subject made conclusion by comparing the aggregate data between the males and the females. It showed the number of students feeling interested in and choosing particular extracurricular activities as their preferred one. The subject argued that there were 2 gender-based data groups of the 4th-graders feeling interested in particular extracurricular activities. It implied that the males were more interested in school cops as their preferred activity, while the females preferred on traditional dance.

3. Discussion

Based on the constructive result divided into four aspects, researcher imaged and described what happened to each aspect related with the statistical thinking in solving statistical problem done by the subjects. The subjects have been interviewed in depth related with four aspects and the relation influences them. The result of the interview to the subjects is presented by describing the statistical thinking in solving contextual statistical problem by the female students with *field independent* cognitive style as the following:

The subjects of the research read the problem and then they understand the problem. They read several times, it is essential to read more than once for them. They explain the problem by imagining the situation of the problem and communicate the problem clearly by restating the problem point by using their own words. The research subjects can also identify concept related with the problem given. They state the relevant and specific data then say them in different forms in the same data. Then, the subjects interpreted by making picture or bar graphic. They also mention the difficulty in solving contextual statistical problem in which the procedure does not use a regular solution or the solution and ability in making formula. Besides, the subjects of the research get a difficulty to apply the good or right strategy because when they read the problem, they directly think to determine the mean or the data centre size. They describe by making mean illustration of straight lines which fulfill each bar. However, when they face the data, the state through extreme data whether the more common data appeared, the most and the least data. The subjects restate all problems with other words with the same problem idea. One of things shown by the subjects can be discussion material is when they determine the centre size simply by giving attention to the extreme values appear. The subjects do not know the centre size data, however they know the most chosen ones, the least, and the most common numbers appear. The subjects observe the extreme values from both table and bar diagram so that they cannot determine the systematic counting when they determine the mean but they assume the close and valid value. Representation done by the subjects also tends to compare or differentiate one data to other data.

From the explanation above, it shows that the female subjects of *Field Independent* cognitive style try to build their understanding to statistical problem by reading it more than once. To make sure that the understanding related with the statistical problem, the subjects restate the problem by using their own words, however the subjects explain the information of statistical problem in the wrong order. Then, when the subjects identify the data with statistical problem, they did not only mentioning the concept ever use in reducing data, but also explain the other concepts in solving the statistical problem.

All of the subjects' activities which appear will influence the development of elementary school students' way in thinking, so they need ability development to think statistically which becomes one of mathematics learning focuses hoped in learning mathematics.

4. Conclusion

Based on the data analysis pointing to the research question, it concludes that the process of statistical thinking of *field-independent* female students at the 4th grade of elementary school in solving statistical problems is as follows. The subject (SPFI) attempted to explore all relevant information either in the form of pictures or mathematical data. Based on the insight she had acquired, SPFI described the data display by her own way

respectively based on the given information provided on the problems. She was able to recognize the different displays yet from the same data. She made an organization through data classification by linking the information to one another. She was able to determine the size of data centralization in simple way, either from the data on table or on chart. In representing the data, the subject was able to make a new data display related to the given data. She showed the correlation of the data between one another and it would be translated into a new display. She was able to give a comprehensively contextual response between the data on table and on chart as well. The subject analyzed the data by comparing them in general manner, observing the extreme quantities that seemed apparent on data, and comparing between the data groups in order to make conclusion to be interpreted, both in the form of table and chart.

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