ISI of undergraduate student

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Informal statistical inference of Indonesian undergraduate students in comparing two groups of data

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Abstract

The latest research examines informal statistical inference, which is supposed to help students to develop their statistical inference skills in a formal way. However, this subject is still under-studied in Indonesia. This study aimed at exploring the students reasoning through informal statistical inferences on comparing two groups of data problem. This study was a qualitative descriptive study involving 97 pre-service teachers at the Universitas Islam Negeri Mataram and the Universitas Islam Malang. The research instruments were worksheet and task-based interview protocols. The results of the study indicated that students could provide an informal explanation of the differences between the two groups of data, such as the influence of the sampling methods and the sample size towards the inference they made. However, the explanation given by the students remained partial and had not been able to apply aggregate-based reasoning appropriately.

Keywords: informal statistical inference, comparing two groups of data.

1. INTRODUCTION

Twenty-first century society is facing unpredictable and complex conditions. The ability to work with data is one of the important skills needed in this situation. These capabilities include the ability to draw conclusions from available data, find trends or patterns, criticize data, apply data to support a claim, and then evaluate it [1]. Therefore, the number of recent research studying statistical reasoning is increasing.

Researchers and teachers are now beginning to develop an apprenticeship that guides students in their statistical thinking rather than focusing solely on the calculations, procedures, and skills [2]. A widely studied topic in statistical reasoning is informal statistical inference, which is considered important in statistical learning [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13]. Although the topic has not been adequately explored in Indonesia.

In general, there are two main concepts of statistics given at the tertiary level, namely descriptive statistics and inferential statistics. Both are given to the students to equip them in analysing data in a research. Descriptive statistics aims to obtain a summary of data which considers "looking at data" aspect, while inferential statistics works toward conclusion drawing about the relationship between the characteristics of the observer groups with more emphasis on the "beyond the data" aspect [14].

At the higher education level, statistics tends to be taught in a more procedural way, as they are considered only as a tool for research analysis. As a result, many students have difficulty in interpreting the results of statistical procedures, particularly with respect to statistical inference. Various researches on this topic shows that students have not been able to draw conclusions correctly and unable to understand the logic on sampling technique and sampling distribution [5],[15],[16]. Students are also have limited understanding of sampling method, sample size, representation, and source bias on certain cases [9],[13],[17].

The idea of statistical inference might be challenging to learn by either high school or undergraduate students. Therefore, those who are just beginning to understand statistical inference need to be introduced to using knowledge informally. Students can develop a deeper understanding of statistical inference through learning basic statistics by using ideas in detail and developing their research-based competence from informal to formal [6],[18]. In addition, if students begin to develop inference ideas informally at the beginning of the learning or program, they have higher chance to learn and to develop better reasoning about formal methods of statistical inference [18]. By introducing informal inference, the opportunities for students to construct proper conceptual framework needed to support their inferential reasoning is higher [19]. According to Makar and Rubin, this reasoning is called informal statistical inference (ISI), which is expressed as a conclusion containing uncertainty and proven by existing data[7].

Comparing the groups of data is one of the ideas in statistical inference. The comparison between two or more groups of data are generally considered to be formal inferences including significance tests, confidence intervals, p-value, and other ideas related to a conclusion drawing about a population based on the observed samples. This comparison, includes the comparison of center, the comparison of center measurement difference towards variability, checking data distribution (normality assumptions, data outliers, and clusters), and sample size effect [10]. To the undergraduate students, the common understanding is the mean difference test using t-test.

Until now, the understanding of mean difference test using t-test on students is still superficial and has not been explored in depth. Students tend to understand the value of both t-test and p-value only to obtain answers on the data significance. Understanding on the meaning of significantly different and in which aspects the data is significantly different and also their implications have not been elaborated widely. According to Engel [21], learning statistical inference is not just about formal methods, but also needs to be taught intuitively to enable students to make better decisions in the uncertain world where the development of diverse domains is characterized using empirical data analysis. One of the tools used to explore the idea of informal statistical inference is the representation of data in the form of box plots.

A box plots is a graphical representations which is very useful to use when comparing multiple groups of data more broadly. The graph is useful because it is easier to compare two or more data sets, which allows us to easily compare central tendency (median), data variability (range and interquartile range) and other location measurement (lower quartile and upper quartile), and identifying outliers that cannot be described in a histogram [19]. A box plot provides an overview of where the data are centered and how they are distributed throughout the range of the variables. Furthermore, a box plot also offers easier way to compare parts of distribution, such as how the third quartile data from the two groups of data could be compared [22]. Moreover, a box plot allows us to compare the visual form of center and distribution of data using five summaries of data, including minimum value, first quartile (lower quartile), median, third quartile (upper quartile), and the maximum value. A part from that, a box plot is also able to describe extreme value, outliers, mean, and significant differences. A boxplot also describes a signal in the form of data center and noise which is in the form of data distribution from the measures of center. This interpretation generates five different points of view which are location information (data), distribution and regional density, global distribution as deviations of median, distribution of upper to lower median, and information classification [10]. In Indonesia, the concept of box plot is not part of the school curriculum, and it is also rarely introduced at higher education levels.

It is possible to understand more meaningful concepts of the comparison of data sets using formal methods such as t-test and Anova if we first introduce an intuitive basis through informal statistical inference. Thus, students' reasoning is not only about deterministic black-and-white paradigm, but rather to a probabilistic reasoning to be able to read what is hidden behind the data [20]. It is important to explore students' capability in informal reasoning on the data sets comparison informally. Therefore, this article describes how students make informal statistical inferences about comparing groups of data problems represented in box plots.

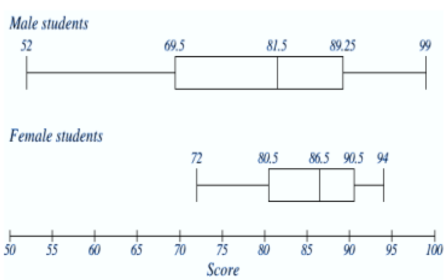
II. METHOD

This study was a descriptive qualitative study with case study. The research was conducted in October to November 2016. The analysed situation was the process of university students' reasoning in solving the comparing two groups of data problem.

Participants in this study included 97 people consisting 57 pre-service teachers of the Universitas Islam Negeri Mataram and 40 pre-service teachers of Universitas Islam Malang. The selected subjects had never taken the Introduction to Statistics subject. The objective of selecting the subjects was to avoid bias that emerged from the subjects' knowledge regarding with formal statistical inference obtained from the inferential statistics subject.

The instruments given to participants were in the form of worksheet containing the problems of comparing two groups of data in the form of mathematics test score of male and female students. The following is the worksheet that have been given to the students:

A study examined the comparison of mathematics test score between 28 male and 40 female students. The data of 14 male and 14 female students had been selected as the research sample drawn in the box plot below.



Question:

1. Please compare the distribution form (symmetry), center, and distribution from both groups of data.

2. If the scores from the two groups are different, which group has better score? Why? Give your reasons!

3. What conclusions do you draw from the comparison of math scores 28 students and 40 students? Does the number of samples support the conclusion?

After distributing the worksheets, the next step was to analyse the responses of the participants based on reasoning elements when comparing two groups of data using the box plot as represented in Table 1. Only eight of the 97 participants met the reasoning elements. The eight participants also gave satisfactory explanation on their worksheet. Next, a task-based interview was conducted to explore their answers. The interview then was transcribed for analysis. After the analysis, it was found out that two of the participants did not provide sufficient data. Thus, a clarification interview was conducted. Two out of eight participants were being participants in the clarification interview. The data of the written answers and transcription of the interview were analysed descriptively.

Table 1. *The Reasoning Elements in Comparing Two Groups of Data using Box Plots [10]*

Elements	Description
Hypothesis generation	Finding patterns on each groups of data
Summary	Comparing the statistical measurements (minimum value, Q_1, median, Q_3 and maximum value) in the box plot.
Shift	Comparing both box plot based on the comparative shift
Signal	Understanding overlapping parts on 50% of data.
Spread	Comparing distribution of the two groups of data, both in the form of intra box plot or inter box plots
Sampling	Understanding the sample size and its influence on the inference drawing
	Moderating Element
Explanatory	Reasoning about the broader context of the data
Individual case	Considering the possibilities of outlier and special case

III RESULT AND DISCUSSION

Students' reasoning for understanding the comparison of two groups of data can be reviewed from four aspects, which are: making a measurable hypothesis, making a descriptive comparison, understanding the contexts, and drawing conclusion or inference. The following is a more detailed explanation of these four aspects.

Making a Measurable Hypothesis

Generally, students have capabilities in making assumptions related to the score comparison between male and female students by considering the presented data in the box plots. A majority of students predicted that the female students had higher scores than the male students. For example, Subject 1 (S1) stated that:

"If I am asked to compare who had better, in my opinion, women did. Because they did not have the lowest score, and also their scores were relatively high" (transl).

The measurability of hypothesis or assumption made by S1 could be deduced from her reasoning by estimating the shape of the distribution curve of each group of data as presented in Figure 1.

The student stated that the female students' scores were better than the male students even though the male students had higher maximum score. The student was also aware that the range of data has an effect on the average value by stating that, "the average score could be going down or becoming imbalance because the minimum score was too low."

S1 compared the scores of the male and the female students by examining the minimum and maximum scores from both groups of data and taking into account their skewness. This shows that the student was able to make a preliminary hypothesis based on the visual interpretation from the form of data in the box plot. The assumption made by the student then was reinforced by the distribution difference from both compared data. This reasoning was part of hypothesis generating element, in which the student is showing capability in finding pattern from the both groups of data being compared.

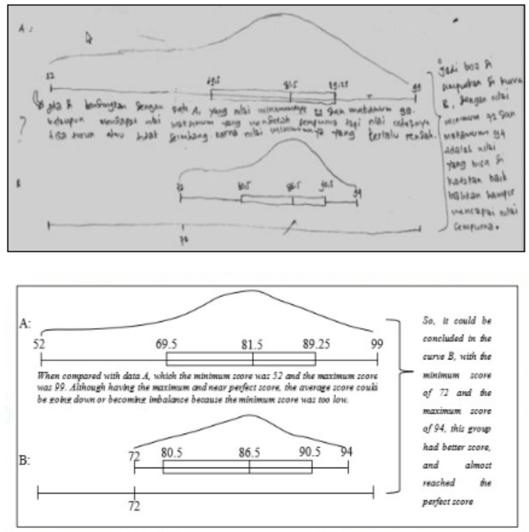


Figure 1. *The Strategy of S1*

Making a Descriptive Comparison

The students were aware that the two groups of data had differences by comparing the statistical measurements presented in the box plot, such as the minimum value, Q1, Q2 (median), Q3, and the maximum value from each group of data. For example, Subject 2 (S2) stated that:

" … the mathematic scores of male and female students were obviously different because the highest score of the male students was higher than the female students', but the lowest score of the female students was higher than the male students' …" (transl).

The other opinion was stated by Subject 3 (S3):

"male and female students' scores were clearly different. This could be seen from the difference of the median, IQR, and also the data distribution" (transl).

Unlike S1 and S2, S4 considered the distance from Q1 to median and the distance from Q3 to median to see the data distribution simmetry by stating:

"The male students' scores were asymmetrical because the distance from Q1 to median is 12 while the distance from median to Q3 is 7.75, whereas the score of the female students is symmetrical as the range from Q1 to the median is 6, and the range from median to Q3 is also 6."(transl).

The students tended to compare both groups of data based on the statistical measurements found without connecting the meaning from each measurement. When asked about the implication from data with longer or shorter IQR, students had failed to provide answers. The students had not yet mastered the ideas about concentration, spread, and distribution of the data.

Most of the students argued that the scores of female students were higher with varied reasons. For example, Subject4 (S4) provided an argumentation in an interview session as follows:

I : Why would you said that the score of female students were higher than the male students?

S4 : I calculated the male students' score IQR, it was 19.75 and the female students' score IQR was 10. The longer the IQR, the more varied the score distribution.(transl).

(On the task sheet answer, S4 wrote, "the longer the IQR, the wider the data distribution. So,it could be concluded that female students have better scores").

Based on the answers, S4 began to understand the notion of data distribution by interpreting "variation" as "the score distribution is possibly more varied". However, the connection between variation and the data distribution had not yet been explained further. Other student (S5) had shown the capability to interpret the distribution from both groups of data and was able to compare it to one another.

I : Why would you said that the score of female students were better?

S5 : Because I derived it from the distribution. The distribution of male students' scores was wider than the female students. I could also see that the difference of male students' score was further than the female ones.

I : You are saying that the distribution of the male students' scores was wider and the female students was narrower. However, you stated that the female students' scores were better. Why??

S5 : If the spread is narrow, then the difference between the scores is smaller. (transl)

Another answer that compared the difference between male and female students' minimum and maximum scores was stated by Subject 5 (S5):

The score of female students were better than the male students' as the difference between minimum score between male and female students was 20, while the maximum score was only 5 point different (transl).

Not only providing narration, the students also argued about data comparison by employing graphs. For example, S1 made an assumption in the form of data distribution (Figure 1) and Subject 6 (S6) formulated data tabulation by using alphabets (Figure 2).

Based on various forms of reasoning given by the students, it could be derived that the students had not only employed the five summary points (summary elements). The students were also aware about the influence of intra and inter groups of data variability towards the spread element. This had been considered as an important aspect in determining which group had the better score.

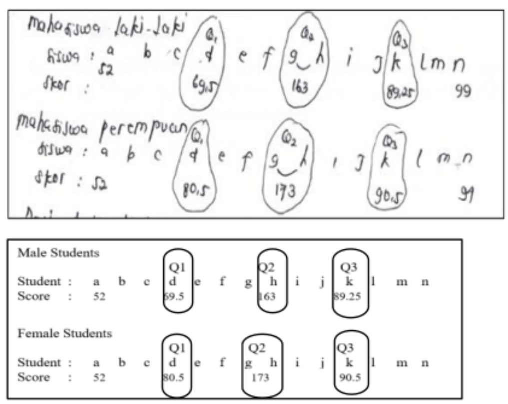


Figure 2. *S6's Strategy*

Understanding the Contexts

The context given in the instruments was the scores in certain subject. The students realized that good score had small distribution and was concentrated on the data of the upper group. The following is an example of the reasoning stated by Subject 7 (S7).

I : If we are talking about the aspect test scores, which one is better?

S7 : If we are talking about scores, I would prefer my students to get 80 in average, rather than get 100 but there are those who get 50.

I : So, in the terms of score, you would prefer small score variation. It would be different if the data context is different, wouldn't it? Do you think both scores are different?

S7 : Yes, they are.

I : Does the difference matter?

S7 : No, it doesn't. It might be ignored (transl).

The students used their knowledge about the context of the data to make justification of their assumption or claim. Their knowledge about the context would determine how deep their reasoning was about the implicit information in the compared data which is very related with explanatory element.

Drawing Conclusion or Inference

After stating that the female students' scores were better than the male students', the students were asked to draw a conclusion about the population based on the comparison of the data sample that had been analysed before. In making an inference on the context of the compared scores, the students tended to pay attention to the sample size and the randomness of the sampling technique (sampling element). Below is the reasoning stated by S5 when considering randomness of the sampling technique:

"If the value or known sample was randomized, then we cannot claim that the male students' scores were lower than the female students' because we are unsure that the remaining 14 male students have high or low scores. If their scores are not randomized, they they may represent the scores of 28 male students, because the score of 14 unknown students must be lower than the 14 known scores". (transl).

Subject 6 (S6) stated the similar reasoning:

"The conclusion for the whole population is certainly not possible if the score were taken randomly, particularly for the female students as the number of samples is lesser than the male students. But if the scores were not taken randomly, then it is possible for the male students' samples to represent the whole male students' population because the sample size is exactly half of the total, so the average value is representative. For the female students, regardless the purposive sampling technique, we cannot draw a representative conclusion for the population because the sample taken was smaller than the whole population in total". (transl)

In addition, S8 has also considered the sampling technique in drawing conclusion about the population:

"The comparison of 28:40 (male population : female population) does not necessarily make female students' scores better than the male ones because we cannot determine that the rest of the population (which are not the sample) have high scores". Transl.

S3 was aware about the element of uncertainty in the conclusion drawing by using the word "not necessarily." In addition, the students also considered the influence of the sample size towards the conclusion about the population, as stated by S4:

I : What about the conclusion for the whole population?

S4 : Well, the number of female students is higher, and then the male students are only 28 people and the sample taken are only 14 people. The female students may have better scores than the male students. But the samples taken are only 14, not necessarily that the rest have higher score.

I : Does the number of samples taken support the conclusion that the female students' scores are better than the male students'?

S4 : It does not because there were a number of scores that had not been tested. It is mean that we cannot draw a conclusion for the whole population that the score of female students are better than male students'.

I : So, in your opinion, how many samples should be taken to support the conclusion?

S4 : Better 28 and 28. Male are all taken, so there are only a few students who have not been tested. (transl)

Other statement related to the sample size was given by S3:

I : Does the conclusion taken support by the sample size?

S3 : If the samples were selected randomly, I cannot be compared. The male students are 14 out of 28 while the female students are 14 out of 40. So, there are many possibilities that female students have lower scores than the male students. See, 50% of the male students were selected, while only 20% - 30% of the female students were taken as the sample.

I : What if the samples were taken purposively?

S3 : If they were not taken randomly, there might be a chance for the sample size to support the conclusion that the female students' scores are better than the male students' (transl).

The overall argument given by the students on the comparison of the two groups of data had not reached an in-depth understanding. Indeed, their prior knowledge was also quite limited. The understanding of the concept inference – drawing conclusion about population based on the data sample and the estimating possible outcomes based on the data sample – had not yet been learned before. The curriculum of statistics at the schools in Indonesia did not accommodate the adequate comprehension of statistical inference.

Statistical inference is essentially about reasoning behind the data by using sampling data to explain the population or to compare sample data to infer possible differences between populations. The goal of statistical inference is to draw conclusion about the relationship between the observed group characteristics [14]. Those characteristics can be in the form of distribution, variability, or the sampling technique. Moving from looking at the data towards beyond the data is the main idea in the informal statistical inference, which can be done by comparing groups of data in box plots.

The results of this study indicated that in comparing two groups of data, the students more focused on the statistical summary in the box plot. The meaning beyond the data had not been explored deeply. The aspects being compared were still partial and unable to demonstrate students' ability to conduct reasoning on the relationship between concepts. It became apparent that the students were still in the stage of looking at the data when making measurable hypothesis, making descriptive comparison, understanding contexts, and drawing conclusion or inference. The students tended to use their understanding about descriptive statistics in making argumentation that support their inference, which is similar to the findings of Konold et al. [23] and de Vetten et al. [5].

Eight elements of reasoning in box plot comparison are not hierarchical, interdependent but can be distinguished [11]. There are four elements of reasoning (hypothesis generation, summary, spread, sampling) that the students can master. In addition, students can explain moderating elements, even with limited explanations. Students may experience this limitation of understanding due to the lack of knowledge about the box plots. This is supported by Grammel, et al. [24] who stated that individual might encounter obstacles when interpreting unfamiliar visual forms. Further, graphic orientation might also cause mistakes in interpreting the box plot [25].

The hypothesis generation included a preliminary assumption made by the students the first time they recognized the data. They used deterministic language in making preliminary assumptions about the data pattern. However, when drawing an inference on the possible difference on the two groups of data the students began to use more probabilistic language.

Summary of the data in the box plot consisted of the minimum score, Q1, median (Q2), Q3 and the maximum score were widely used by the students to compare the two groups of data. The students tended to compare equivalent statistical measurements, although some were able to compare inequivalent statistical measurements.

Students tended to use the middle 50% distribution (box) in their explanation partially in each group of data. However, they were unable to find an overlap between the boxes in the two groups of data samples compared. Boxplot describes signal (center) and noise (the data distribution from the center) [10]. Element of shift includes the observation towards the plot as a whole (box and whisker) and comparison of differences between plots. The element of shift and signal are related to each other, but the focus point of shift is the comparison of the entire data. This was what students failed to figure out.

With regards to the idea of sampling, the students drew conclusion about the population taking into account the uncertainty in the randomness of sampling technique and the sample size (as given in the instrument). The students were aware of the effect of random sampling towards possible conclusion drawing about the population. Similarly, in the account of the idea of sample size, students were thinking that the disproportionate sample sizes provided uncertain predictions about the difference in the data distribution of the two groups.

The spread component in the data which showed the distribution variability was also able to be explained by the students by considering the difference of data IQR and making estimated graphs of each data. The data distribution could also be treated as the basic of inference drawing when associated with the context of the data which were the scores of mathematics subject. Students used their initial knowledge about context to determine the possible difference in the two groups of data.

Data context played an important role in drawing informal statistical inferences. Students used the context of data to find the meaning of the observed pattern [26]. When solving a comparing groups of data problem, students used context to express their new knowledge or additional information, explaining the data, giving justification or qualification about the claim, identifying useful data to complete the task, and stating facts that are able to increase the data description but irrelevant for data analysis process [27]. The result of this study demonstrated that the students abled to use context to give new insights on the data that were not explicitly stated in the tasks given. In addition, the context of the data was also used by students to support their assumptions or claims about the possible differences in the two groups of data compared.

When the students were completing the task sheets, they had difficulties in providing explanations on how significant was the difference between the two groups of data. According to Pfannkuch [10], this is due to informal decision-making under uncertainties. It is more challenging than formal inference in the form of statistical tests as it needs deeper qualitative considerations. The students had not yet arrived at the significance of the differences between the two groups of data because their reasoning was still at the informal and intuitive level, and had not yet reached the mastery of the concept of formal statistical inference.

It appeared that the students had also experienced obstacles in comparing data holistically. The students had tendencies to think partially by comparing only each of the points in the summary statistics and by exploring less the meaning of comparison of data groups with the context being discussed. This showed that students tended to view the data locally rather than globally or in other words they did not apply the aggregate-based reasoning. This type of reasoning defines as an understanding of the distribution as a whole, which form are either data center, spread, and distribution [19]. The reasoning comprises of the utilization of trend and pattern of the whole data groups to communicate descriptions, to make comparison, and finally to make decision. Therefore, this reasoning is considered as one of the most basic and powerful elements in handling data in a statistical procedure [28]. Aggregate-based reasoning could be developed in students' cognitive by engaging them at an inquiry-based learning setting, by priory introducing intuitive comparison method, then initiating more formal method.

IV CONCLUSIONS

Comparing the two groups of data in box plots had helped the students to develop their informal statistical inference. The students were able to provide informal explanation about the difference of the two groups of data, as well as the influence of sampling method, sample size, and the context of data towards drawing inference. However, the students' explanation was still partial and had not yet integrated ideas about distribution as a whole. The students were only able to implement four of eight elements of reasoning when comparing two groups of data using box plot which are hypothesis generation, summary, spread, and sampling. They had not yet succeeded in applying an aggregate- based reasoning appropriately.

This research can be employed as a recommendation for teachers and instructors to design statistics learning related to the idea of comparison between two or more groups of data both at high schools or higher education levels.

Advanced research should be conducted in deeper inferential context, such as on the sample size, sampling variabilities, and the emergent of the outliers. Further research should be conducted by utilizing intervention setting in the form of inquiry-based learning environment with varieties of tasks containing a wider context that enables learners to perform an in-depth reasoning.

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