Jurnal Pengembangan Pembelajaran Matematika (JPPM)
Volume 5, Issue 1, February 2023
Available online at: https://ejournal.uin-suka.ac.id/tarbiyah/jppm/index
Print ISSN : 2656-0240, Online ISSN : 2655-8750

ANALYSIS OF STUDENT-TEACHER STATISTICAL REASONING ABILITY

Nayla N Ghassaniy*, Aan Hasanah, Wahyudin
Mathematics Education, Universitas Pendidikan Indonesia, Jalan Dr Setiabudhi No 229, Bandung, 40154, Indonesia

Email: nayla.nafisa@upi.edu
* Corresponding Author

Received: 23-12-2023	*Revised: 02-01-2023*	*Accepted: 22-02-2023*

ABSTRAK

Peneliti dan guru secara ekstensif menggunakan statistik untuk memperdalam pengetahuan akademik atau menganalisis peningkatan siswa. Oleh karena itu, banyak perguruan tinggi yang mewajibkan mahasiswanya untuk mengambil mata kuliah statistika setidak-tidaknya sebagai syarat kelulusan. Salah satu tujuan kelas statistika adalah untuk mengintensifkan kemampuan penalaran statistika siswa. Penelitian ini bertujuan untuk menganalisis tingkat penalaran statistik siswa-guru. Penelitian dilakukan dengan menggunakan studi kasus kualitatif yang dibagi menjadi tiga tahap untuk menilai penalaran statistik siswa-guru. Pertama, kami mengadopsi tugas penalaran statistik dari penelitian sebelumnya. Selanjutnya, kami menguji 32 peserta dari siswa-guru semester empat. Akhirnya, tingkat penalaran statistik diklasifikasikan berdasarkan jawaban peserta. Hasil penelitian menunjukkan bahwa penalaran statistik siswa berada pada level idiosyncratic, transisional, kuantitatif, dan analitis, dengan persentase tertinggi pada level idiosyncratic. Hasil penelitian ini menunjukkan bahwa kemampuan penalaran statistik siswa-guru masih perlu diperhatikan, sehingga diperlukan penelitian lebih lanjut untuk meningkatkan kemampuan penalaran statistik siswa-guru. Penelitian ini diharapkan dapat memberikan kontribusi pengetahuan bagaimana mengkategorikan kemampuan penalaran statistika pada siswa-guru, sehingga praktisi dapat mendeteksi kekurangan yang harus diperbaiki.
Kata Kunci: statistika, penalaran statistika, siswa-guru

ABSTRACT

Researchers and teachers extensively use statistics to deepen academic knowledge or analyze students' enhancement. Therefore, many universities require their students to take a statistics class leastwise as a graduation requirement. One of the objectives of statistics class is to intensify the statistical reasoning ability of students. This study aimed to analyze the statistical reasoning level of the student-teacher. The research was conducted using a qualitative case study divided into three stages to assess students'-teacher statistical reasoning. First, we adopted the statistical reasoning task from prior research. Next, we tested 32 participants from the fourth-semester student-teacher. Finally, the statistical reasoning level was classified based on the participants' answers. The results showed that students' statistical reasoning was at the idiosyncratic, transitional, quantitative, and analytical levels, with the highest percentage at the idiosyncratic level. The results of this study indicate that statistical reasoning abilities at the student-teacher still need attention, so further research is needed to improve student-teacher statistical reasoning abilities. This research is expected to contribute knowledge in how to categorize statistical reasoning abilities at the student-teacher, so that practitioners can detect deficiencies that must be improved.
Keywords: statistics, statistical reasoning, mathematics, students-teacher

How to cite

Ghassaniy, N. A., Hasanah, A., & Wahyudin,. (2023). Analysis of student-teacher statistical reasoning ability. *Jurnal Pengembangan Pembelajaran Matematika*, 5(1), 31-42. https://doi.org/ 10.14421/jppm.2023.51.31-42

INTRODUCTION

In the beginning, humans used statistics to describe conditions and solve statehood problems, but over time statistics have taken part in sundry disciplines of knowledge, such as education and psychology, agriculture, social, and science (Hanief & Himawanto, 2018). Researchers and teachers widely use statistics to intensify academic knowledge in education. Because of the many needs, statistical application techniques have increased over the year; universities require so many students to take leastwise a statistics class as a graduation requirement (Onwuegbuzie & Wilson, 2003). In statistics education, there is something called statistical reasoning. This term arises because there is an assumption that students do not have statistical reasoning with learning through traditional approaches (i.e., focus on teaching statistics about competencies, operations, and calculations (Ben-Zvi & Garfield, 2004).

The importance of discussion about statistical reasoning begins from Ben-Zvi & Garfield (2004) statement that teaching statistics has to focus on statistical literacy, reasoning, and thinking. However, in defining, there is much contention. Ben-Zvi & Garfield (2004) revealed that when they read the references about how to enhance statistics teaching, there are no clear definitions to distinguish literacy, reasoning, and thinking learning goals. The differences and similarities of these terms are significant in formulating learning objectives for students. Because of this, the first Statistical Reasoning, Literacy, Thinking (SRTL-1) research forum emerged in Israel in 1999 to discuss this. The first conference contains several reasoning, literacy, and statistical thinking definitions. The second forum (SRTL-2) was held in Australia in 2001, focusing on discussing types of reasoning abilities. Furthermore, the forum is held every two years.

Although there is no formal agreement on the definitions and distinctions of literacy, reasoning, and thinking, researchers have some thoughts about the terms. There are many forms of explanation for statistical reasoning. Generally, it refers to how people justify with statistical interpretation and makes statistical information plausible (Garfield & Gal, 1999). For instance, they make inferences based on data and make representations or conclusions from data.

Martin et al., (2017) highlight statistical reasoning, statistical literacy, and statistical thinking differences. In contrast, they may assess literacy and reasoning with neutral content. Still, they do statistical thinking tests using a context, such as asking a student to evaluate and critique a study's designs and conclusions. Sabbag et al., (2018) also revealed the difference between literacy statistics and reasoning statistics. The most underlined difference is that statistical literacy might comprise criticizing information that only uses one concept of statistics. On the other hand, statistical reasoning applies two or more. For example, a student has to interpret the graphics first and then make connections between them to evaluate so that he can make data-related arguments critically.

delMas (2002) summarizes the similarities and differences in literacy, reasoning, and statistical thinking according to Rumsey, Garfield, and Chance, who are still overlapping, then provides an alternative perspective to distinguish the three terms. According to delMas (2002), Rumsey, Garfield, and Chance did not clearly explain the differences between literacy, reasoning, and statistical thinking. Often the definition of one term combines the capabilities of one or two other terms. For example, Garfield reveals many examples where the terms statistical reasoning and statistical thinking are used alternately in the various sources. The condition will be a problem if the aim is to distinguish the three terms. However, the overlap shows that one instructional activity can potentially develop more than one learning outcome when viewed from an instructional perspective. One example of overlapping definitions from Rumsey and Chance is as follows. Rumsey revealed that if students know how data is used to make decisions, it shows they have data awareness, meaning that they are at the statistical literacy level. Having an awareness of knowing how data is used is in line with Chance's views on statistical thinking. Chance said that statistical thinking is knowing how to think like a statistician. Chance also explained that students who show data awareness have statistical reasoning abilities because students are reasoning statistical ideas and giving meaning to statistical information. Due to the overlap, delMas (2002) provides an alternative perspective to distinguish literacy, reasoning, and statistical thinking by looking at learning outcomes from literacy, reasoning, and statistical thinking. These learning outcomes can be distinguished through the instructions from the test items.

Jones et al., (2004) assume that we can assess students' reasoning by considering the four statistical processes (i.e., data description, data organization, representation, and analysis and interpretation). Data description means reading the presented data in a table, graph, or graphical representation. In comparison, data organization comprises compiling, grouping, or combining data in a recap. Furthermore, data representation involves showing data in graphics. The last is analyzing and interpreting; it is the statistical reasoning essence. In this process, students need to recognize the data trends and patterns to make inferences and predictions.

There are four levels (i.e., "idiosyncratic, transitional, quantitative, analytical") to classify statistical reasoning ability (Jones et al., 2001). Student reasoning is limited to subjective reasoning, often not according to the data provided, and instead focuses on individual personal assumptions at an idiosyncratic level. Irrelevant sides of the problem may disorient student reasoning at an idiosyncratic level. Students begin to realize the importance of reason at a transitional level. They correctly do the task but only focus on one aspect of the circumstances. At the quantitative stage, the reasoning of students is still quantitative. They can analyze mathematical concepts from a task and are not disoriented by unrelated facets. However, students cannot integrate these ideas when engaged in assignments. Finally, Student reasoning is built upon creating connections between various elements of a problem fettle at the analytical stage. Their reasoning can combine the pertinent parts of the problem into a purposeful composition (e.g., making more than one view of the data or making plausible predictions).

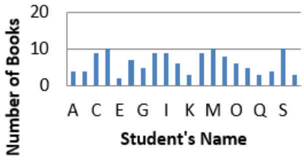
Therefore, students-teacher at least have the quantitative level in their statistical reasoning to use statistics in the field they will be inside.

Researchers in other countries and Indonesia have conducted studies about statistical reasoning. The result is that students' statistical reasoning is still low and needs more attention to increase (Ganesan & Eu, 2018; Idris, 2018; Kesumawati & Octaria, 2019; Lavigne & Lajoie, 2007; Lee & Kim, 2019; Olani et al., 2011; Rohana & Ningsih, 2020; Rosidah et al., 2018). Likewise, the researchers conducted studies that aim to look at the statistical reasoning of middle school, high school, or mathematics student-teacher. However, in Indonesia, it seems that rarely research the student-teacher. Nevertheless, at the same time, statistical reasoning is also essential for them. So this research aimed to analyze the students-teacher statistical reasoning.

METHODS

The researchers conducted a qualitative case study with the following steps to investigate students'-teacher statistical reasoning. First, the researchers adopted the statistical reasoning task, according to Saidi & Siew (2019). This task complies with the framework for Students' Statistical Reasoning Assessment and has been analyzed for validity and reliability. Mathematics experts then theoretically validate the test to ensure the instrument's suitability with fourth-semester students. We can see the instrument in Table 1.

Table 1. Elements Allocation in the Instrument

<table>
<tr><th>Statistical Process</th><th>Description</th><th>Ite m</th><th>Task</th><th>Question</th></tr>
<tr><td>Data Description</td><td>Indicating consciousness of data display</td><td>3a</td><td>3</td><td>Scrutinize the chart. Describe the information that you see from the chart.

</td></tr>
<tr><td>Data Organization</td><td>Concluding data based on spread measures</td><td>3b</td><td>3</td><td>From the chart in number 3a. How is the spread of data? Clarify how you decide the value!</td></tr>
<tr><td>Data Representation</td><td>Presenting data from the existing data set</td><td>1</td><td>1</td><td>From the data below,
Data Nilai Matematika Kelas VII
<table><tr><td>79</td><td>90</td><td>37</td><td>61</td><td>52</td><td>85</td></tr><tr><td>69</td><td>50</td><td>56</td><td>29</td><td>45</td><td>60</td></tr><tr><td>51</td><td>75</td><td>88</td><td>41</td><td>70</td><td>89</td></tr><tr><td>26</td><td>23</td><td>80</td><td>47</td><td>72</td><td>51</td></tr><tr><td>83</td><td>34</td><td>52</td><td>85</td><td>44</td><td>75</td></tr><tr><td>60</td><td>38</td><td>88</td><td>21</td><td>66</td><td>89</td></tr><tr><td>87</td><td>34</td><td>39</td><td>82</td><td>46</td><td>59</td></tr><tr><td>30</td><td>41</td><td>76</td><td>42</td><td>58</td><td>88</td></tr><tr><td>90</td><td>49</td><td>68</td><td>29</td><td>63</td><td>63</td></tr><tr><td>20</td><td>84</td><td>82</td><td>48</td><td>64</td><td>84</td></tr></table>Could you present the data differently? Then, explain what you are going to do!</td></tr>
<tr><td>Data Analysis and Data Interpretation</td><td>Reading between data</td><td>2</td><td>2</td><td>In your opinion, which type of central tendency measure (mean, median, mode) is best suited to represent a data set? Clarify why!</td></tr>
</table>

Second, the researchers tested 32 students from the fourth-semester student-teacher to investigate students' statistical reasoning using the instruments shown in Table 1 within 90 minutes. Previously, students had learned about statistics. Students come from a University in Bandung, Indonesia. Furthermore, the researchers conduct interviews and observations to investigate the reasons for making profound conclusions about the answers and ask participants to express what they thought and tell the thinking process. The researchers conducted the interview session through a recorded Zoom application.

Third, the researchers analyzed student-teacher answers by classifying them based on statistical reasoning. The researchers consider four levels of statistical thinking. We can see how the students' statistical reasoning by doing this classification. Therefore, the researchers used a preliminary framework. Saidi & Siew (2019) formulated a framework to assess students' statistical reasoning. The framework showed in Table 2.

Table 2. A Preliminary Framework for Students' Statistical Reasoning Assessment for Each Item

Statistical Process	Description	Item	Idiosyncratic	Transitional	Quantitative	Analytical
Data Description	Indicating consciousness of data display	3a	Indicating no consciousness of the data displayed	Indicating only a consciousness of the data displayed	Indicating some consciousness of the displayed features	Indicating complete consciousness of the data displayed
Data Organization	Concluding data based on spread measures	3b	Unable to conclude data based on spread measures	Understanding the measurements of spread but can not conclude using the valid measures	Figuring the data utilize measures of spread, but there are some faults in the step	Inferring the data using accurate and correct measurements of the spread
Data Representation	Presenting data from the existing data set	1	Unable to present data from the existing data set	Presenting data partially from the existing data set	Presenting for the existing data set completely, but the display may have some minor fault	Makes a data presentation for the existing data set completely, with no fl
Data Analysis and Data Interpretation	Reading between data	2	Takes mistaken comparisons inside and among data sets	Gives conclusions that are partly upon the data. Some findings may only make partial sense	Gives conclusions mainly based upon the data. Some findings may only make partial sense	Gives reasonable conclusions upon the data and the context

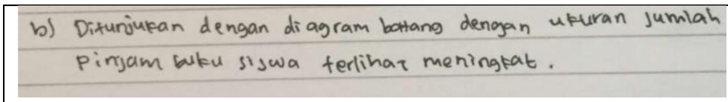
RESULT AND DISCUSSION

This section will explain the results and discussion of this research. Table 3 presents students' reasoning ability classification based on task results.

Table 3. Students' Reasoning Ability Classification Based on Task Results

Item	Level	Amount	(%)
3a	Idiosyncratic	16	50
	Transitional	10	31
	Quantitative	4	13
	Analytical	2	6
3b	Idiosyncratic	31	97
	Transitional	0	0
	Quantitative	0	0
	Analytical	1	3
1	Idiosyncratic	20	63
	Transitional	2	6
	Quantitative	4	13
	Analytical	6	19
2	Idiosyncratic	21	66
	Transitional	5	16
	Quantitative	6	19
	Analytical	0	0

Students are at the idiosyncratic level in the four abilities (i.e., describing, organizing, representing, analyzing, and interpreting data). Figure 1 shows an example of a student's answer.



Translated Version

Indicated by a bar chart with the size of the number of increasing students' books read.

Figure 1. Example of Student's Work at Idiosyncratic Level

Based on Figure 1 the student can not conclude data based on measures of spread. Therefore, in this item, the researchers created a trick. The question does not immediately ask for standard deviation but the data spread. As a result, most students cannot answer the question, even though they studied standard deviation. The student's answer appears that he was distracted by subjective reasoning and not following the problem in question. At the idiosyncratic level, students' personal experiences or subjective beliefs affect students' reason. Student's reasoning at this level may be confused by unrelated aspects (Jones et al., 2000, 2001; Saidi & Siew, 2019; Sánchez et al., 2011).

As can be seen from the general finding, from item number one to three, more than 50% of students' answers are still influenced by student experiences, not based on the data provided. Instead, focus on individual personal assumptions. As in Chan et al. (2016), Rohana & Ningsih (2020), and Rosidah et al. (2018). Rosidah et al., (2018) studied students with high and low mathematical abilities. The result shows that they all know the algorithm and procedures to solve the standard deviation problem. They solve the calculation well, but they have no idea about the standard deviation concept, so they cannot conclude the results. Furthermore, Rohana & Ningsih (2020) found there are many students' statistical reasoning at level one (lowest level). Chan et al. (2016) are shown in the variable map of the Rasch Measurement model analysis. They notice that most students are located below the zero logits. Lower logits manifest in students with lower ability. It means that the students' statistical reasoning ability was inferior.

Students are at the transitional level in describing, organizing, representing, analyzing, and interpreting data. Figure 2 shows an example of a student's answer.

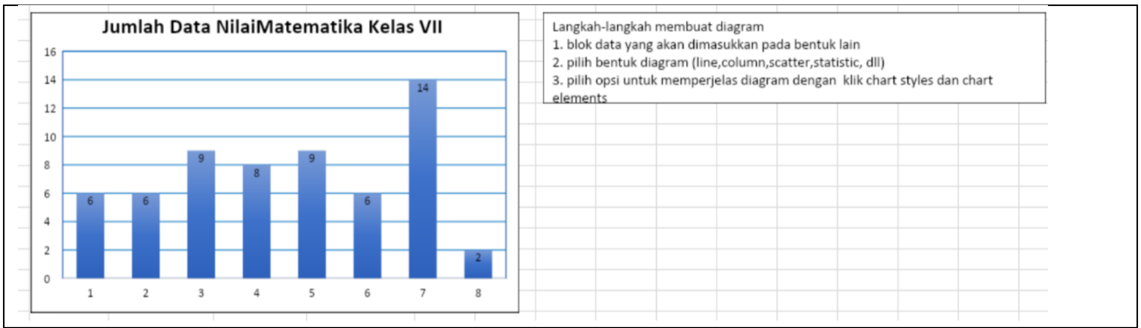
3a. Informasi apa yang anda dapat daro grafik tersebut ? jumlah buku yang dibaca siswa bulan maret 2021	**Translated Version** *Number of students' books read in March 2021*

Figure 2. Example of Student's Work at Transitional Level

Upon the student's work results, the student has an idea about the displayed features at the transitional level but shows only single awareness. Students at this level begin to use the quantitative message in statistical problems and therefore begin to demonstrate quantitative reasoning; however, they do this in a limited way. Students only understand the problem at this transitional level and relate it to a data set as the arithmetic mean (Jones et al., 2000, 2001; Saidi & Siew, 2019; Sánchez et al., 2011).

Several students are at the transitional level. They correctly do the task but only focus on one aspect of the circumstances. Rosidah et al. (2018) also found that students with high and low mathematical ability solve problems with the correct procedure on the concept of data-centering but cannot interpret the context in context, especially on median concepts. All students in their study have destitute conceptions and reasoning in descriptive statistics, especially in determining median and standard deviations.

Students are at the quantitative level in describing, organizing, representing, analyzing, and interpreting data. Figure 3 shows an example of a student's answer.



Translated version:

Diagraming Steps:

1. *Block of data to be entered on another form.*
2. *Select a chart shape (line, column, scatter, statistic, etcetera.*
3. *Select the option to clarify the chart by clicking chart styles and chart elements.*

Figure 3. Example of Student's Work at Quantitative Level

In this case, the student can use the concept of constructing data. The student can create a data display for a given data set, but the display may have some minor errors. Label naming is unclear, making it difficult to interpret. Student's reasoning at the quantitative level is steadily quantitative and able to establish the mathematical concept, but students do not naturally integrate this pertinent mathematical concept when doing the task (Jones et al., 2000, 2001; Saidi & Siew, 2019; Sánchez et al., 2011).

They can analyze mathematical concepts from a task and are not disoriented by unrelated facets. However, students cannot integrate these ideas when engaged in assignments. The finding is similar to Ulusoy & Altay (2017) and Vetten et al. (2016). When they asked the pre-service teacher to describe a data table set, Ulusoy & Altay (2017) found that the participants could not establish a connection between measurements of central tendency and variation. Indeed they have a limited or mistaken reason. For example, when there is a data set, most participants think the only value representing the data set is the arithmetic mean. Additionally, Ulusoy and Altay found that although the pre-service teachers correctly computed the measures of variation, such as standard deviation and interquartile range, they did not know what these measures told them about the data set variation.

Vetten et al. (2016) asked three first-year pre-service teachers to generalize a population and predict a larger sample graph during three rounds with increasing sample sizes. The research result is that most pre-service teachers described only the data and showed a limited finding of how a sample can represent the population.

Students are at the analytical level in describing, organizing, and representing data. Figure 4 shows an example of a student's answer.

b. Bagaimana penyebaran data jumlah buku yang dibaca siswa pada Bulan Maret2021? Jelaskan dengan ukuran apa dan bagaimana cara anda mendapat nilai tersebut!

Persebaran data jumlah buku yang dibacapada bulan maret sangat beragam, dengan ukuran standar deviasi dan juga varians untuk mendapatkan nilai tersebut kita dapat menggunakan rumus standar deviasi dan juga varians

untuk data tersebar

$$s=\sqrt{\frac{\sum(x_i-\bar{x})^2}{n-1}}=\sqrt{\frac{n\sum x_i^2-(\sum x_i)^2}{n(n-1)}}$$

untuk data berkelompok

- tanda kelas

$$s=\sqrt{\frac{\sum f_i(x_i-\bar{x})^2}{n-1}}=\sqrt{\frac{n\sum f_i x_i^2-(\sum f_i x_i)^2}{n(n-1)}}$$

- standar deviasi duga

$$s=p\sqrt{\frac{\sum f_i d^2}{n}-\left(\frac{\sum f_i d}{n}\right)^2}$$

$$d=\frac{(x_i-\bar{x})}{p},\quad \bar{x}=AM$$

Translated version:

The value of the data distribution can be searched with the standard deviation and variance

Figure 4. Example of Student's Work at Analytics Level

In Figure 4, the student can conclude the data using accurate and correct spread measurements, even though there is a trick in the question. At the analytical level, students can integrate the pertinent aspects of the assignment into an essential structure (Jones et al., 2000, 2001; Saidi & Siew, 2019; Sánchez et al., 2011).

Student reasoning is built upon connecting various elements of a problem fettle at the analytical stage. Their reasoning can combine the pertinent parts of the problem into a purposeful composition (e.g., making more than one view of the data or making plausible predictions). Although students' statistical reasoning is still low, it can be the basis for improvement. There are researches about increasing statistical reasoning. For example, Mavrotheris & Mavrotheris (2006) improve early statistical reasoning teaching and learning in European schools by leveraging distance education to offer high-quality professional development experiences to teachers across Europe. Biehler et al. (2013) conducted a literature study on the role of technology in improving students' statistical reasoning abilities. The software can help improve students' statistical reasoning skills, including Fathom and TinkerPlots. Fathom was then applied in the Ganesan & Eu (2018) study. Conway et al. (2019) investigated the impact of the appropriateness of the statistical reasoning learning environment (SRLE) principles on students' statistical reasoning in an advanced placement statistics course. In addition, They use a quasi-experimental design to compare the level of conformity of the teacher's teaching method with the principles of SRLE through a matching process used to reduce the effect of non-random assignments. The result shows that beliefs and practices aligned with SRLE principles can improve students' statistical reasoning above the national average. Showalter (2021) has implemented an SRLE using the experimental method. The results show that students who study with SRLE have good interest and learning outcomes.

CONCLUSION

The researcher obtained students' ability to describe data at idiosyncratic, transitional, quantitative, and analytical levels. However, they are wrong in reading graphs at an Idiosyncratic level and cannot capture the available charts correctly. Students can only name one statement from the graphs at the transitional level. For the quantitative level, students can mention some of the information from the chart, and students at the analytical level can fully note all the information on the graph. Moreover, students are at the idiosyncratic and analytical levels in data organizing skills, while there are no students at the transitional and quantitative levels. Students cannot summarize the data at the idiosyncratic level according to the size of the data spread, even though they already know how to calculate the standard deviation. The reasons for these phenomena need to be studied in more detail. However, the student at the analytical level can summarize data using valid data distribution measurements. In representing data, students at the idiosyncratic level do not make the desired data representation. At the transitional level, students can represent data, but it is not complete. Students can represent the data entirely at the quantitative level, but there are few errors, while at the analytical level, students can represent the data entirely without mistakes. Data analysis and interpretation skills are at the idiosyncratic, transitional, and quantitative levels. Students make incorrect comparisons within and between data sets at the idiosyncratic level. Students can give conclusions that are partly upon the data. At the transitional status, some findings may only make partial sense. Students can give conclusions mainly upon the data; some decisions may only make partial sense at the quantitative level. Finally, students can give reasonable conclusions upon the data and the context at the analytical level.

The results showed that the highest percentage of students' statistical reasoning is idiosyncratic. Therefore, there needs to be an effort to improve the statistical reasoning of students-teacher. This research is expected to contribute knowledge in how to categorize statistical reasoning abilities at the student-teacher, so that practitioners can detect deficiencies that must be improved. In addition to the conclusions above, the researcher realizes some limitations in this study. First, the researchers are only investigating the results of student work. Therefore, triangulation of data is minimal. In addition, the researcher only researched 32 participants, so the researcher cannot make generalizations. In the future, the researcher recommends conducting more in-depth research through interviews and a more significant number of students to learn more about students' statistical reasoning abilities and to find the causes of low statistical reasoning ability and how to enhance it.

REFERENCES

Ben-Zvi, D., & Garfield, J. (2004). *The Challenge Of Developing Statistical Literacy, Reasoning And Thinking*. Netherlands: Kluwer Academic.

Biehler, R., Ben-Zvi, D., Bakker, A., & Makar, K. (2013). Technology for enhancing statistical reasoning at the school level. In *Third International Handbook of Mathematics Education* (pp. 643–689). Springer, New York. https://doi.org/10.1007/978-1-4614-4684-2_21

Budde, L., Frischemeier, D., Biehler, R., Fleischer, Y., Gerstenberger, D., Podworny, S., & Schulte, C. (2020). Data Science Education In Secondary School: How To Develop Statistical Reasoning When Exploring Data Using Codap. *International Association for Statistical Education*. https://www.mpfs.de/

Chan, S. W., Ismail, Z., & Sumintono, B. (2016). Assessing Statistical Reasoning In Descriptive Statistics : A Qualitative Meta-Analysis. *Jurnal Teknologi*, 78 (6-5). https://eprints.um.edu.my/15604/1/assessing_statistical_reasoning_indescriptove_statisctics_a_qualitative_meta_analysis_.pdf

Conway, B., Gary Martin, W., Strutchens, M., Kraska, M., & Huang, H. (2019). The Statistical Reasoning Learning Environment: A Comparison of Students' Statistical Reasoning Ability. *Journal of Statistics Education*, 27 (3), 171–187. https://doi.org/10.1080/10691898.2019.1647008

DelMas, R. C. (2002). Statistical literacy, reasoning, and thinking: A commentary. Journal of Statistics Education, 10(2). https://doi.org/10.1080/10691898.2002.11910674

Ganesan, N., & Eu, L. K. (2018). Effectiveness of Fathom on Statistical Reasoning Among Form Four Students. *Malaysian Online Journal of Educational Sciences*, 6 (4), 12–22. http://adum.um.edu.my/index.php/MOJES/article/view/13847

Garfield, J., & Gal, I. (1999). Teaching and Assessing Statistical Reasoning. *Developing Mathematical Reasoning in Grades K-12: National Council Teachers of Mathematics 1999 Year,* 207–219. https://www.researchgate.net/profile/Iddo-Gal/publication/247700710_Teaching_and_assessing_statistical_reasoning/links/55ef4c7208ae199d47c00a72/Teaching-and-assessing-statistical-reasoning.pdf

Hanief, Y. N., & Himawanto, W. (2018). Statistik pendidikan. Sleman: Deepublish.

Idris, K. (2018). Teaching and learning statistics in college: How learning materials should be designed. *Journal of Physics: Conference Series,* 1088. https://doi.org/10.1088/1742-6596/1088/1/012032

Jones, G. A., Langrall, C. W., Mooney, E. S., & Thornton, C. A. (2004). Models of Development in Statistical Reasoning. In: Ben-Zvi, D., Garfield, J. (eds) *The Challenge of Developing Statistical Literacy, Reasoning and Thinking.* Springer, Dordrecht. https://doi.org/10.1007/1-4020-2278-6_5

Jones, G. A., Langrall, C. W., Thornton, C. A., Mooney, E. S., Wares, A., Jones, M. R., Perry, B., Putt, I. J., & Nisbet, S. (2001). Using students' statistical thinking to inform instruction. *Journal of Mathematical Behavior*, 20 (1), 109–144. https://doi.org/10.1016/S0732-3123(01)00064-5

Jones, G. A., Thornton, C. A., Langrall, C. W., Mooney, E. S., Perry, B., & Putt, I. J. (2000). A Framework for Characterizing Children's Statistical Thinking. *Mathematical Thinking and Learning,* 2(4), 269–307. https://doi.org/10.1207/s15327833mtl0204_3

Kesumawati, N., & Octaria, D. (2019). Developing Statistics Learning Equipment Based on the PMRI Approach Oriented to Students' Statistical Reasoning Ability. *Jurnal Pendidikan Matematika,* 10(1), 87–99. https://doi.org/10.24042/ajpm.v10i1.3614

Lavigne, N. C., & Lajoie, S. P. (2007). Statistical reasoning of middle school children engaged in survey inquiry. *Contemporary Educational Psychology*, 32(4), 630–666. https://doi.org/10.1016/j.cedpsych.2006.09.001

Lee, S., & Kim, G. (2019). How middle-school mathematics textbooks of Korea and the US support to develop students' statistical reasoning. The Mathematical *Education*, 58(1), 139–160. https://doi.org/10.7468/mathedu.2019.58.1.139

Martin, N., Hughes, J., & Fugelsang, J. (2017). The Roles of Experience, Gender, and Individual Differences in Statistical Reasoning. *Statistics Education Research Journal, 16(2),* 454–475. https://doi.org/https://doi.org/10.52041/serj.v16i2.201

Mavrotheris, M. M., & Mavrotheris, E. (2006). Enhancing Early Statistical Reasoning in European Schools by Building an Online Professional Community of Practice. *International Conference on Information Communication Technologies in Education.* https://www.researchgate.net/publication/283256788

Olani, A., Hoekstra, R., Harskamp, E., & van der Werf, G. (2011). Statistical Reasoning Ability, Self-Efficacy, and Value Beliefs in a Reform Based University Statistics Course. *Electronic Journal of Research in Educational Psychology,* 9(1), 1696–2095. https://doi.org/10.25115/ejrep.v9i23.1427

Onwuegbuzie, A. J., & Wilson, V. A. (2003). Statistics Anxiety: Nature, etiology, antecedents, effects, and treatments--a comprehensive review of the literature. *Teaching in Higher Education,* 8(2), 195–209. https://doi.org/10.1080/1356251032000052447

Rohana, R., & Ningsih, Y. L. (2020). Students’ Statistical Reasoning In Statistics Method Course. *Jurnal Pendidikan Matematika,* 14(1), 81–90. https://doi.org/10.22342/jpm.14.1.6732.81-90

Rosidah, Ketut Budayasa, I., & Juniati, D. (2018). An Analysis of Statistical Reasoning Process of High School Students in Solving the Statistical Problem. *Journal of Physics: Conference Series,* 1028(1). https://doi.org/10.1088/1742-6596/1028/1/012125

Sabbag, A., Garfield, J., & Zieffler, A. (2018). Assessing Statistical Literacy And Statistical Reasoning: The Reali Instrument. *Statistics Education Research Journal*, 17(2), 141–160. https://doi.org/https://doi.org/10.52041/serj.v17i2.163

Saidi, S. S., & Siew, N. M. (2019). Reliability and Validity Analysis of Statistical Reasoning Test Survey Instrument using the Rasch Measurement Model. *International Electronic Journal of Mathematics Education*, 14(3), 535–546. https://doi.org/10.29333/iejme/5755

Sánchez, E., da Silva, C. B., & Coutinho, C. (2011). Teachers' Understanding of Variation. In New *ICMI Study Series* (Vol. 14, pp. 211–221). Springer. https://doi.org/10.1007/978-94-007-1131-0_22

Showalter, D. A. (2021). Attitudinal changes in face-to-face and online statistical reasoning learning environments. *Journal of Pedagogical Research,* 5(2). https://doi.org/10.33902/jpr.2021269257

Ulusoy, A. C., & Altay, K. M. (2017). Analyzing the Statistical Reasoning Levels of Pre-Service Elementary School Teachers in the Context of a Model Eliciting Activity. International *Journal of Research in Education and Science* (IJRES), 3(1), 20–30. www.ijres.net

Vetten, A. de, Schoonenboom, J., Keijzer, R., & Oers, B. van. (2016). Exploring Student Teachers' Reasoning About Informal Statistical Inference When Engaged In A Growing Samples Activity. *International Congress on Mathematical Education*, 1–4. https://www.researchgate.net/publication/305700143